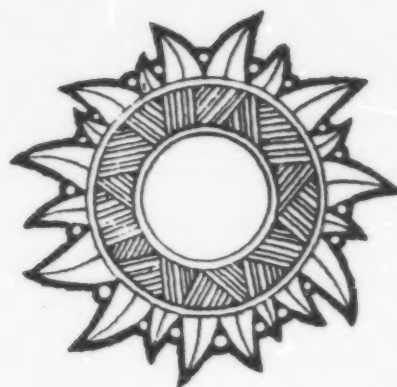




Global Warming and Climate Change

Tuesday, May 12, 1992

Victoria Conference Centre
Victoria, B.C.

Sponsored by

BChydro 



The B.C. Environmental Network (Energy Caucus)

Torrie and Associates

Canadian Cataloguing in Publication Data

Main entry under title:

Global Warming and Climate Change

Sponsored by B.C. Hydro, The B.C. Environmental
Network (Energy Caucus) and Torrie and Associates

Held May 12, 1992 at the Victoria Conference
Centre, Victoria, B.C.

ISBN 0-7718-9293-4

1. Global Warming – Congresses. 2. Climate
Changes – Congresses

I. B.C. Hydro. Communications Planning

QC981.8.G56G56 1992 363.73'922
C92-092384-4

October 1992

Typesetting and Production Design Management by Patrick J. Meehan, Vancouver
Printed in Canada on recycled and recyclable Canadian paper by Gastown Printers Ltd.

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SUMMARY

Neale Adams

Introduction

The atmosphere seems vast, as vast as the blue sky, in size, almost beyond comprehension. We are told emissions from human activity might be altering the atmosphere, causing the earth to warm significantly. What event, or series of events, could be so powerful as to alter this huge ocean of air? It's hard thing to visualize.

One might begin to get a picture in the mind by first considering the surface of the earth, both land and water. The area of the earth's surface seems massive. It's about 500 million square kilometres. Resting on top of each square kilometre is a column of atmosphere about 400 kilometres high. But the atmosphere quickly becomes very sparse at higher elevations - if that air column were compressed to the density of air at sea level, it would be only about ten kilometres thick.

We can think of the earth as surrounded by a very thin shell of atmosphere, equivalent to roughly five billion cubic kilometres of air at sea level. Five billion also happens to be approximately the current world population. So it works out, quite neatly, that every one of us - man, woman, and child - in effect, has about a cubic kilometre of atmosphere to foul.

While the atmosphere may be almost beyond our visual comprehension, one can hold a picture of a cubic kilometre in the mind: a volume ten (Canadian) football fields long and wide and high. A cubic kilometre may still seem like a lot of air - it weighs roughly a million tons; however, it isn't able to absorb unlimited pollutants.

According to Worldwatch, an environmental group, the Canadian per capita production of fossil fuel

carbon emission is about four tons annually. That is, each of us adds about four tons of mostly carbon dioxide to our 'quota' of one million tons of air, that's four parts per million. On a per capita basis, only the United States emits more carbon than does Canada; their rate of emission is about five tons per person.

When one starts altering parts per million in a gas, effects may start to become measurable. According to the analysis of air trapped in ancient glaciers, atmospheric carbon dioxide may fall to about 200 parts per million by volume (ppmv) during ice ages, then rise to 300 ppmv during warm periods. Since the Industrial Age began about 200 years ago, atmospheric carbon has risen in concentration from about 300 to 350 ppmv - historically, a very rapid increase. Yet that concentration of carbon dioxide threatens to increase at an even more dramatic rate as the Third World industrializes.



**First Panellist:
Dr. Gordon McBean**

The panel discussion on global warming was opened by one of the world's leading experts on the topic: Dr. Gordon McBean, professor and chair of the Atmospheric Science Program of the Departments of Geography and Oceanography at the University of B.C. Dr. McBean spoke not only about global warming due to greenhouse gases, but also how that warming may be linked to ozone depletion.

Earth is unique in having a temperature that averages about 15°C, making life as we know it possible. Without some greenhouse gases to trap long-wave radiation from the sun within the atmosphere, average temperatures would be much lower (calculated to be -18°C). On the other hand, too much of a greenhouse effect would warm earth beyond a life-supporting temperature. Venus, for instance, with a thick carbon dioxide atmosphere, averages an unbearable 477°C. Only Earth, like Baby Bear's porridge, is neither too hot nor too cold, but just right.

Since the turn of the century, the average temperature of earth has increase between 0.3°C and 0.6°C. Though the trend lines are not clear cut, it does appear that the 1980s was the warmest decade on record. The sea level has risen 10-20 centimetres over the same period, due mainly to the warming and melting of small land glaciers. Still, Dr. McBean was careful to add: "This warming could be entirely due to natural variability and cannot be attributed to the impact of increasing greenhouse gas concentrations."

What is so frustrating to the lay person about the global warming controversy is that this temperature change is less than one might expect from the additional carbon dioxide. Atmospheric dynamics are not simple.

Carbon dioxide is only one of several greenhouse gases. Ozone, another greenhouse gas, reflects radiation from the surface of the earth back into the atmosphere. It is generally agreed by the scientific community that ozone at higher elevations has been depleted due its interaction with man-made chlorine compounds. It is possible that the reduction in one greenhouse gas, ozone, may at least partially offset the increase in another greenhouse gas, carbon dioxide.

Other greenhouse gases (methane, nitrous dioxide, chlorofluorocarbons) affect the overall picture. Methane concentration has, for example, been increasing at a rate more than twice as fast as carbon dioxide; chlorofluorocarbons are the fastest growing greenhouse gas (by 5 to 10 per cent per year).

However, the most significant unknown is the role of Earth's oceans in global warming. The oceans contain about 50 times as much carbon dioxide as does the atmosphere. How much of the excess carbon dioxide produced over the past century has been soaked up by the oceans? How much more can the oceans take? We simply don't know. Yet it is crucial for us to find out how the oceans act as a carbon dioxide 'sink.' "It is important that the origin and nature of natural climate variations be understood," Dr. McBean said. Without that knowledge, it is very difficult, indeed, impossible to predict the future.

"It is unrealistic to think that global greenhouse gas emissions are going to be reduced by the amounts

necessary to even stabilize present concentrations," said Dr. McBean. "The sources of carbon dioxide are everywhere; they result from processes fundamental to our global economy." An international agreement to control substances that deplete the ozone layer was not easy; building an international consensus on how to reduce carbon emissions promises to be a much more difficult task.



**Second Panellist:
Mr. Douglas Russell**

What the international community in general and Canada in particular should do about climate change has been the concern since late 1990 occupying Douglas Russell, director of the climate change convention negotiations office of the Atmospheric Environment Service of Environment Canada. That office has been a focal point for consultation with provincial governments, industry, environmental groups, and customers, all involved in preparing Canada's international position.

Preparatory to the United Nations Conference on Environment and Development in Rio de Janeiro, some 147 nations agreed on terms for a Framework Convention on climate change. Agreement was difficult to reach; the developed and developing world had differing agendas. North America, Europe, Japan and other industrialized areas were concerned that cutbacks in greenhouse gases would affect their trade competitiveness; less developed countries were determined controls not slow their economic development. Some states had special concerns, especially island states (the Maldives, Tuvalu, and Kiribati), for whom even a small rise in the sea threatens their very existence.

"Perhaps nowhere in the current global economic and political landscape are international tensions and differences played out as they are in building a global response to climate change," said Mr. Russell.

The European Community wanted the treaty to specify that carbon dioxide emissions would be cut to 1990 levels by the year 2000. However, specific legal targets and schedules for greenhouse gas reduction were rejected at the insistence of the United States. Instead, the New York session early in May adopted admittedly ambiguous statements calling on industrial nations, including former Communist countries, to recognize that reducing emission 'to earlier levels' by the end of the century will contribute to fighting climate change.

Mr. Russell said that the Canadian government's 1991 Green Plan declares that this country intends to

stabilize carbon dioxide emissions and other greenhouse gases at the 1990 level by 2000. Canada will also attempt to reduce the demand for energy; to price energy to encourage emission reduction; and to encourage better urban planning and public transit use. Provincial governments and individuals will be encouraged to take action to reduce emissions.

The Canadian government is taking action despite uncertainties about global warming because it believes the "...lack of full scientific certainty should not be used to postpone action," Mr. Russell said. On the other hand, it is pleased the treaty uses not only "...a balanced approach involving not only regulation, but also market forces, recognizing efficacy of applying economic instruments in a cost-effective manner." It is also extremely important to continue scientific efforts to understand the phenomenon.



**Third Panellist:
Dr. Brian O'Brien**

The next panellist stressed the dangers of taking action without an adequate knowledge base. Dr. Brian O'Brien, an Australian environmental consultant, has held professorships in Iowa and Texas, as well as at the University of Sydney, and has worked for the government of Western Australia. In remarks that drew much response, some of it angry, he said he considered much of the scientific work on the global warming issue more like an environmental 'Holy War' than a rigorous scientific inquiry.

Echoing Dr. McBean, he pointed out that it has not yet been proven with scientific certainty that the increased concentration of greenhouse gases has caused the observed rise in the Earth's temperature. "Cause and effect have to be watched very, very carefully indeed." A graph of recent temperature change and carbon dioxide levels does not show a simple correlation.

Dr. O'Brien said two facts are undeniable: that greenhouse gases do indeed trap heat within the atmosphere, i.e., an infrared effect exists, and these gases are increasing in concentration in the atmosphere by parts per million. On what Dr. O'Brien considers a slim factual basis, a great many assumptions, scenarios, predictions, and models have been built.

In particular, he objected to scientists at the 1988 Toronto international conference on global warming stating that carbon dioxide emission should be reduced by 20 per cent from current levels by the year 2005, the so-called Toronto target. He asserted 20 per cent was a

number plucked from thin air, without scientific basis, and such a reduction would have relatively little effect on the rate of increase in atmospheric carbon. In the light of uncertainties as to carbon dioxide processes, Dr. O'Brien has termed the Toronto target 'scientific nonsense.'

Similarly, assertions made in 1988 that the seas could rise by 30 centimetres but possibly as much as 1.5 metres by 2050, were decreased two years later by scientists of the Intergovernmental Panel on Climate Change (IPCC) to 20 centimetres by 2030 and 65 centimetres by 2100. At second glance, scientists came to believe that if the world warms, more moisture laden air will flow over Antarctica, depositing more snow and ice on that continent.

Paradoxically, an initial effect of global warming could be a build-up of the polar ice caps. Thermal expansion of the oceans and the melting of land glaciers might still tend to raise the level slightly; still, the net effect would be a much smaller rise in sea levels than first predicted.

Dr. O'Brien argued that it does not make sense to adopt an 'alarmist urgency' before our knowledge is more certain. However, forcing industry, because of the so-called global warming, to cut back carbon dioxide production is a position adopted by many environmental groups which for various reasons want a cutback in economic growth.



**Fourth Panellist:
Dr. Louis Hobson**

The fourth panellist, Dr. Louis Hobson, professor and chairman of the Biology Department at the University of Victoria took the discussion back to the problem of the ozone layer. The thinning of the ozone layer, and the resulting increase in ultraviolet light reaching the earth's surface, may affect some lifeforms, especially the microscopic plants (phytoplankton) in the seas. Some of these plants appear to take carbon dioxide from the surface and then descend into the ocean's depths.

While at earth's mid-latitudes, it appears that ultraviolet light has little effect below a few metres, plankton seem to be affected at the extreme latitudes down to depths as great as 25 metres. In addition, many species of fish and shellfish lay eggs near the surface. We do not yet know what effect increased ultraviolet light will have on them. It seems possible that ozone depletion could significantly reduce the ability of the oceans to absorb carbon dioxide.



**Fifth Panellist:
Dr. Michael Margolick**

Michael Margolick, senior resource planning coordinator for B.C. Hydro, has been working on electricity conservation and recently completed a study for the World Energy Council on greenhouse gas taxation. It turns out that there is no simple way to impose a so-called 'carbon tax' to discourage high emissions.

A government could simply mandate low emissions. It could tax on the basis of emissions. What might be economically the most effective, but difficult to administer, could be a system of pollution credits in which companies earning credits for low emission are allowed to sell these credits. For a limited time, companies purchasing the credits would be allowed to operate with emission levels higher than otherwise permitted. 'Licensing pollution' in this way should, according to economic theory, lead to faster overall compliance, due to competitive pressures: the 'clean' companies would have increased income and be earning higher profits, while the 'dirty' companies would face higher costs.

In British Columbia, questions arise as to whether mills should be taxed for burning wood waste, since that waste left in the forests would decay and put carbon dioxide into the air also. Dr. Margolick noted, too, that in countries that have imposed carbon taxes (mostly in Scandinavia), heavy industry has generally been exempted, since such firms can relocate their operations (and jobs).



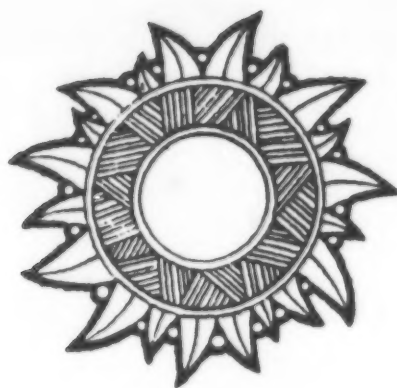
**Final Panellist:
Dr. Douglas Ross**

Political scientist Dr. Douglas Ross of Simon Fraser University said that whatever the scientific uncertainties of global warming, the world's leaders are genuinely fearful of the implications of climate change.

In particular, they fear massive population movements caused by droughts and other natural disasters. Environmental refugees could come to outnumber political refugees. Hence, there has been relatively fast action from the global community in coming to agreement on a climate change convention. The question, as always, is whether such action has been fast enough, and whether the strong 'business as usual' attitude in the U.S. can be overcome.

Following the panel discussion, the audience of about two hundred people participated in a lively question period. Several people questioned Dr. O'Brien's arguments. Some felt the Rio Treaty was too timid and should have contained set targets for greenhouse gas reduction, as the European Community urged. Several questions dealt with the ozone depletion, and suggested that Canada should immediately order an end to the production of CFCs. Solar power was suggested as an alternative to the burning of fossil fuels. It was suggested that the issue of population control must be dealt with, an issue many less developed countries don't want to discuss. Moderator **Eve Savory**, CBC National Science reporter, was kept busy with so many questioners eager to take the microphone.

Meanwhile, the concentration of greenhouse gases in each cubic kilometre of atmosphere that 'belonged' to each member of the audience kept building up. In the face of uncertainty, the question remained that the panel did not - and could not - agree upon: exactly what should be done to ensure the continuance of life as we know it on this complex planet, our only home.



Panel Discussion: Global Warming and Climate Change



Eve Savory is a reporter specializing in environmental subjects with the Canadian Broadcasting Corporation (CBC). Prior to her current assignment, she was a science and medicine specialist, reporting on new developments in science and health, space exploration and a broad range of environmental issues. Ms. Savory received the 1989 Canadian Science Writers' Award for excellence in broadcasting, for her series on the Voyager spacecraft's journey to Neptune. She has also won the Hollobon Award, a silver medal, at the 28th International Film and TV Festival for her medical and scientific broadcasting. Ms. Savory has worked as a general news reporter and legislative reporter at CBC stations across Canada.

Panel Discussion

Global Warming and Climate Change

Panellists

Gordon McBean
Douglas Russell
Brian O'Brien
Louis Hobson
Michael Margolick
Douglas Ross

Introduction of Panellists by Eve Savory

Good evening everybody, and welcome to our Global Warming Forum. I'm Eve Savory, and it's my honour to act as the moderator of this session. Tonight, we'll hear from a number of eminent speakers, followed by a question and answer period. I want some stimulating and challenging questions from you people in the audience.

About four years ago, I saw a reporter begin a story with the sentence, "It's now well-accepted that the hole in the ozone layer is probably letting in more of the sun's rays and that will warm the Earth." I don't think anyone would write that now. I think that now it's generally much more accepted by the public, they have a far greater understanding of what the greenhouse effect is and what the greenhouse problem may be, and I say 'may be,' because tonight we have someone who will challenge that statement.

You have heard of the possible consequences of global warming: a dramatic rise of the sea level, inundation of parts of Prince Edward Island and all of Richmond below the level of the dykes, the melting of the permafrost beneath the tundra, our wheat belt turning into a corn belt, fires ravaging our forests and incredible storms. I've even heard it said that the Gulf Stream may switch direction, and who knows what that might do to northern Europe. Your awareness of the problem is important and whether or not one comes down on the side that says, "It's an important debate, but more research is needed and we should wait." or the side that says, "The consequences could be so serious that we have to act now." The most critical thing is that we listen to the facts and we debate these issues.

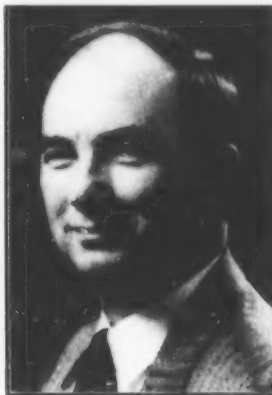
The first speaker tonight is Dr. Gordon McBean. He's Professor and Chair of the Atmospheric Science Program of the Departments of Geography and Oceanography at the University of British Columbia. Before that he was a senior scientist with the Canadian Climate Centre, part of the Atmospheric Environment Service of Environment Canada, and he's also chair of the World Meteorological Organization International Council for Scientific Unions Joint Scientific Committee, part of the World Climate Research Program. He also serves on numerous scientific councils and committees. Among other honours, he was awarded the 1989 Patterson Medal for distinguished contributions to meteorology, which is the highest honour for a Canadian Meteorologist.

Some years ago, when I was looking for a scientist in Vancouver to talk of global warming, the one name on everyone's lips was Gordon McBean. He's now going to give us his views on global warming.

Climate Change and Ozone Depletion: The Linkage

1. Introduction

Global climate change due to an enhanced greenhouse effect and depletion of the ozone layer are two environmental issues that are frequently reported in the media and have become familiar terms to the general public. From both the scientific and policy response points of view, these issues have interesting similarities and dissimilarities. The purpose of this presentation is to explore what we know, and do not know, about the scientific aspects of these environ-



mental issues and to discuss how they are linked.

2. History of the Planets - Development of Greenhouse Gases and Ozone Layer

It is first appropriate to talk about our planet, Earth. Earth is the only planet in our solar system that can maintain life as we know it. What are the unique characteristics of Earth that have made this possible? Basically, these are temperatures that are not too hot nor too cold, water in liquid form and an atmosphere with oxygen we can breathe and an ozone layer to shield us from most of the Sun's ultraviolet radiation. In the begin-

ning, there was no life on any of the planets. Eventually, outgassing of water vapour and carbon dioxide from the surface provided an atmosphere. Until this stage, Earth, Venus and Mars had similar histories. However, on Mars, the temperatures were so cold that the outgassing water vapour froze, and the thin atmosphere that formed is more than 80% carbon dioxide. On Venus, with warmer temperatures (it is closer to the Sun), the water vapour remained a gas and its heavy atmosphere became more than 90% carbon dioxide. On Earth, the water vapour condensed to liquid clouds, leading to rain and eventually to oceans. The rain also reduced the amount of carbon dioxide in the atmosphere, so that through most of the Earth's history carbon dioxide has constituted less than 0.1% of the atmosphere.

The presence of water vapour and carbon dioxide in the atmosphere had another effect on planets. First, it is necessary to recognize that solar radiation from the Sun consists of short-wavelength radiation: ultraviolet radiation, visible light and near-infrared radiation. Most of this radiation passes through a cloudless atmosphere and warms the Earth's surface. The Earth and its atmosphere themselves (as well as all other objects) also emit radiation. However, since they are much cooler than the Sun (which has a temperature of 5,700°C), the emitted radiation is long-wave radiation. Long-wave radiation is absorbed by water vapour, carbon dioxide and some other gases in the atmosphere.

The effect is to trap heat energy in the atmosphere and warm the climate. This is called the greenhouse effect and water vapour, carbon dioxide, methane, nitrous oxide, ozone and other gases with these properties are called greenhouse gases. The impact of these gases on Mars, Earth and Venus was quite different. Because Mars' atmosphere was very thin, the greenhouse effect only slightly warmed the planet so its temperature remained well below freezing (average observed temperature is -47°C), while Venus' thick carbon dioxide atmosphere raised its temperature by over 500°C to an unbearable 477°C. On Earth, the temperature was raised from below freezing (calculated to be -18°C without the greenhouse effect but with the same reflective properties) to the present value of about 15°C. The result of the greenhouse effect was to provide Earth with a temperature that was not too hot nor too cold, just right.

Because the water vapour on Earth condensed to rain and formed the oceans, it provided a place for life to start. Subsequently, oxygen was released into the atmosphere, probably from the respiration of early plant life, which used up carbon dioxide and gave up oxygen. The breakup of oxygen molecules by the Sun's radiation led to the formation of the ozone layer, tens of kilometres above the Earth's surface. Hence, the greenhouse effect, an originally entirely natural phenomenon, played a major role in regulating the Earth's temperature and indirectly to the formation of the ozone layer, which provided the opportunity for life to form and flourish.

For most of the Earth's 4.5 billion year history, human activities had no impact on either the greenhouse effect nor the ozone layer. From information derived from ice and sediment cores and other sources, it is known that the climate of the Earth has varied between ice ages and warmer periods. Over the past 160,000 years, the Earth's temperature decreased 5-7°C during glacial periods, and was 1-2°C warmer 120,000 years ago, during inter-glacial periods. At the same time, the atmospheric concentration of carbon dioxide varied from about 200 parts per million by volume (ppmv) during the glacial periods to about 300 ppmv during the warm periods. Similar records for the ozone layer do not exist. However, over the past 200 years, the atmospheric carbon dioxide concentration has increased to over 350 ppmv with much of the increase occurring in the last 50 years. More recently, the concentration of ozone in the stratosphere has been decreasing. In both cases, the scientific evidence is very strong that the changes are due to human activities.

The atmosphere is divided into several layers that encircle the globe. The lowest 10-15 km is called the troposphere. Weather dominates the troposphere and convective storms mix it vertically while large low pressure cyclones mix it horizontally. Rain and clouds are important. Many pollutants emitted into the troposphere fall or rain out in a few days to a few weeks. Some, however, have very long lifetimes. The next layer, extending up to about 50 km, is the stratosphere which has very slow vertical mixing, few clouds and little water vapour. While the temperature of the troposphere is in equilibrium with the Earth's surface through vertical mixing, the stratosphere, which is cold (the lower stratosphere is -50 to -70°C), is heated by absorbing energy from incoming and outgoing radiation. The higher layers of the atmosphere are not important for this discussion. Because the density of the atmosphere decreases rapidly with height, about 50% of the atmospheric mass is below 6 km elevation and about 95% is below 20 km.

3. The Ozone Layer

The important ozone layer is in the lower stratosphere, between 15 and 30 km elevation. Ozone molecules absorb the ultraviolet component of incoming solar radiation, heating the stratosphere and shielding the lower atmosphere and Earth's surface from harmful ultraviolet-B (UV-B) rays. Studies have shown that the incidence of skin cancer is related to the intensity of UV-B radiation. UV-B radiation apparently also causes the body's immune system to be less effective and increases the incidence of eye diseases such as cataracts. Laboratory studies have shown that UV-B decreases photosynthesis in many plants and harms plankton and other marine life that inhabit the upper ocean. Scientific evidence is strong that decreasing ozone concentrations will increase the UV-B radiation incident on Earth and have harmful effects on humans and plants and animals, both on land and in the oceans.

Note that ozone in the stratosphere is natural and essential; ozone at ground level is a noxious chemical which is toxic to both plants and animals. In natural circumstances, there would be very little ground-level ozone but increased concentrations of pollutants, such as nitrogen oxides, have led to the formation of large amounts of ground-level ozone in certain localized areas. Although this is an important local pollutant, it does not yet have much impact on the global ozone values and will not be considered further here.

Measurements of atmospheric ozone concentrations have been under way since the 1950s. Most measurements are of the total amount of ozone in a column of air over the location of measurement, which is given in Dobson units. Annual average values were (before 1980) about 260 Dobson units over the tropics, increasing to 340-380 Dobson units over mid-latitudes and then decreasing to about 300 Dobson units over the poles (less over Antarctica). Concentrations of ozone vary considerably during the year as ozone is both generated and destroyed by the interaction of the Sun's radiation with normal molecular oxygen and other chemical processes and moved around by the winds. The lifetime of an individual ozone molecule is only a few days.

Analyses of observations of ozone amounts over Antarctica, published in 1985, showed a marked decline in total column ozone in October, from about 320 Dobson units (in the 1950s and early 1960s) to about 280 Dobson units in 1975 and then a more dramatic decrease thereafter (to 180 Dobson units in 1985). It was not clear at first what caused the 'ozone hole,' as it came to be called. Special high-altitude aircraft observations in 1987 revealed very large amounts of chlorine ions, probably created from the Sun's radiation breaking up CFC mole-

created through the breakup of a CFC molecule, can destroy 100,000 or more ozone molecules.

Recent observations reveal depressions in the total ozone content of the Arctic as well, but these depressions are shallower, smaller in extent and duration and are not bonded to topographic features as their Antarctic counterpart. It is likely that future ozone depletion will depend on the atmospheric levels of chlorine and similar compounds and on the particular meteorology of each Arctic winter.

Stratospheric ozone concentrations undergo large variations in space and time. For example, ozone concentrations can be more than 400 Dobson units in polar regions in spring to less than 250 Dobson units at the equator year-round. It should be remembered that although the public attention is focused on polar ozone holes, typical ozone concentrations are less in the tropics where the solar intensity is also largest. In Antarctica, ozone concentrations can naturally vary by as much as 50% between spring and autumn. The ozone hole in Antarctica has lowered the value by more than 130 Dobson units, in the southern spring, when the concentration should be near their maximum. These variations make it difficult to interpret individual measurements and to determine longer-term trends.

The 1991 United Nations Environment Programme-World Meteorological Organization Assessment concluded that observations of ozone amounts from both ground-based instruments and satellite now show significant decreases in total-column ozone in both the northern and southern hemispheres, but not in the tropics (see Table 1). The heaviest losses are in the winter in the southern hemisphere.

Table 1. Total Ozone Trends (% per decade with 95% confidence limits; UNEP-WMO, 1991).

Season	Satellite: 1979 - 91			Ground-based: 24-64°N	
	45°S	Equator	45°N	1979 - 91	1970 - 91
Dec - Mar	-5.2±1.5	+0.3±4.5	-5.6±3.5	-4.7±0.1	-2.7±0.7
May - Aug	-6.2±3.0	+0.1±5.2	-2.9±2.1	-3.3±1.2	-1.3±0.4
Sep - Nov	-4.4±3.2	+0.3±5.0	-1.7±1.9	-1.2±1.6	-1.2±0.6

cules, in the Antarctic stratosphere and the presence of stratospheric clouds which are formed only at very low temperatures. It is believed the ozone destruction is instigated by reactions which occur on the surface of these cloud particles releasing destructive catalysts. The strong polar vortex inhabits the exchange of heat between the Antarctic and warmer lower latitudes. With spring, sunlight appears and the released destructive catalysts destroy ozone and are responsible for the Antarctic ozone hole. CFCs were developed and used because their stability meant a long (75 to 110 year) lifetime and no apparent harmful reactions with other things. However, when exposed to the strong solar radiation CFCs do break apart and act as a catalyst to destroy ozone. It is estimated that one free chlorine ion,

International response to the depletion of the ozone layer led to the Montreal Protocol of 1987. The Protocol committed the signatory countries to reducing emissions of ozone-modifying substances (primarily CFCs) to 50% of 1986 levels by 1999. However, as the scientific evidence accumulated, it was realized that this would not be adequate to defend the ozone layer. The subsequent London agreement of 1990 led to an agreement to entirely phase out the most damaging CFCs and halons by 2000. Since then, several countries including Canada, have declared their intention to achieve this target by 1997. However, since CFCs are already in wide use and have very long lifetimes, the atmospheric concentration of CFCs will continue to be high through much the next century.

4. Global Climate and the Greenhouse Effect

The earth's climate has warmed 0.3 to 0.6°C during the last century and the 1980s was the warmest decade on record. However, this warming could be entirely due to natural variability and cannot be attributed to the impact of increasing greenhouse gas concentrations. Stratospheric temperatures have decreased in the past decade or two, which may be due to ozone depletion and an increase in carbon dioxide. It is possible that this decrease may cause climatic change through dynamic linkages. The sea level has risen 10-20 cm over the same period, mainly through thermal expansion of the ocean waters due to warming and melting of small land glaciers.

The climate system may be thought of as being controlled by a 'fast system' and a 'slow system.' The fast system is mainly determined by the atmospheric heat engine which drives the whole earth environment and determines the ultimate amplitude and geographical patterns of climate change. Adjustments in the fast climate system are very complicated and involve feedback processes which amplify or reduce the primary greenhouse effect. Water, in the form of vapour and clouds, plays the dominant role in the greenhouse effect. However, the water content of the atmosphere adjusts very rapidly and its atmospheric concentration is not being significantly modified, on a global basis, by human activities. The long-lived greenhouse gases whose concentrations are being changed, are carbon dioxide, methane, nitrous dioxide, ozone and chlorofluorocarbons. Although carbon dioxide is the main greenhouse gas, the others are also important.

The slow climate system is controlled by the global ocean, which sets the pace for climatic change and may introduce a delay of decades in the transient response of the earth's climate to greenhouse forcing. The temperature change of the past few decades is less than could be inferred directly from the imbalance of the radiation budget due to the observed increase in greenhouse gases. We may be underestimating the lag of the oceans, or perhaps overestimating the positive feedback of the fast climate system or other influences that could be counterbalancing increasing greenhouse gases. For example, recent studies have suggested that increasing northern hemispheric concentrations of sulphate aerosols from human activities may be increasing the earth's reflection coefficient (resulting in more solar radiation being reflected back to space) and hence acting to cool the planet. There is also the natural process whereby natural sulphate released from the ocean may cause changes in cloud albedo and influence the climate. It is difficult to detect greenhouse gas-induced global warming because of natural variability and other factors. It is important that the origin and nature of natural climate variations be understood.

The problem of predicting future climate change, induced by human activities, cannot be separated from that of understanding and predicting natural variations.

Typically, every 4-5 years the eastern tropical Pacific Ocean warms, leading to disastrous consequences for the local fishery. We now know that the 'El Niño' is part of a much larger natural variability of the coupled ocean-atmosphere-land climate system. In 1982-83, the strongest El Niño of the century occurred, with extreme droughts in many regions and floods in others. The recent mild winter in western Canada may be attributable to the El Niño of 1991-92. Scientists are now showing skill in predicting the occurrence of El Niños up to a year ahead. For much of the past 20 years, the Sahel region of Africa has been ravaged by drought, causing great suffering to this region. Although human activities are compounding these problems, it is clear that natural variability must be understood and predicted better to enable societies to respond to its impacts.

The concentration of carbon dioxide, which alone accounts for more than half the enhanced greenhouse effect due to long-lived gases in the past, has increased by 25 per cent since the beginning of industrialization. The dominant importance of carbon dioxide is expected to continue in the future. Methane concentrations have been increasing at a rate more than twice as fast as carbon dioxide. The atmospheric concentration of nitrous oxide has increased by almost 10% in the past century. Changing ozone concentrations are also important for the radiative forcing of climate. Chlorofluorocarbons are the fastest growing greenhouse gas (by 5-10% per year). It should be noted that the atmospheric concentrations of the longer-lived greenhouse gases (carbon dioxide, CFCs and nitrous oxide) adjust only slowly to changes in emissions. Because of uncertainties in future emissions, projections on climate warming rates will also be uncertain. It should also be emphasized that the anthropogenic emissions are but small increments on the large exchanges between the atmosphere and the oceans or land. Relatively minor adjustments in the natural system could significantly affect future atmospheric greenhouse gas concentrations.

To understand the uncertainties in climate simulations for enhanced atmospheric concentrations of greenhouse gases, it is useful to consider the following segments of the problem. Over the next decades to centuries, human-caused emissions of greenhouse gases to the atmosphere are likely to increase, but their actual variations are difficult to predict. Presently about 50% of the human-caused emissions of CO₂ remain in the atmosphere and the remainder are absorbed in the oceans or on land. The total response of the climate system to these additional greenhouse gases will depend on the climate system feedbacks or amplifiers. Present climate models of the fast system (the atmosphere coupled to a shallow ocean) indicate that the global mean warming for doubled concentration of carbon dioxide will be 1.5 to 4.5°C. A major unresolved problem is that of predicting accurately the role of clouds and generally water in its various phases. Also, the models need to be able to predict the regional changes in the

global water cycle, including precipitation. An additional complication that is now becoming more apparent is the role of aerosols in climate. The time-dependent response of the climate system to this additional radiative forcing will depend on the response of the slowest component, the oceans. This will result in a lag and/or reduction in climate change. The oceans also play an important role in the cycling of greenhouse gases, such as carbon dioxide. The exchanges of carbon between the ocean and the atmosphere are many times larger than the human-generated emissions. How these exchanges are controlled and how they will alter in the future (as they probably altered in the past) is not well understood.

concentrations lead to warmer temperatures. In the ozone case, the decrease in ozone concentrations are large enough that we can confidently say that the changes are not natural; in the climate case, the changes to date are still small and may be natural, but they are also consistent with aerosols-accounting model predictions.

The sources of CFCs are small in number and most of their manufacture takes place in developed countries. Although CFCs are important for some industries, these industries constitute a relatively small part of the overall global economy and substitutes for CFCs are now being manufactured. Therefore, to gain international agreement

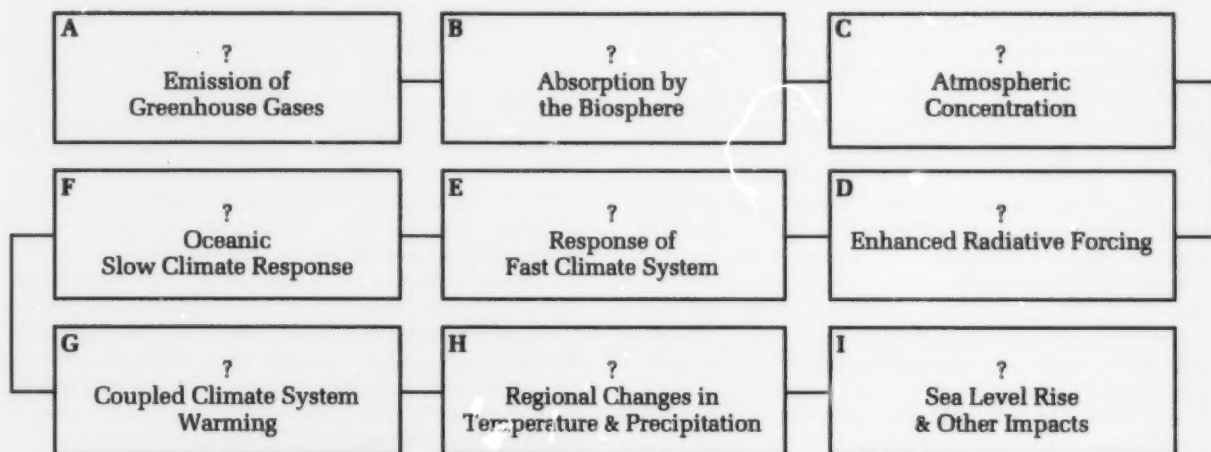


Figure 1. Schematic Diagram of the Factors Determining the Change in Climate due to Increasing Greenhouse Gas Concentrations.

Each factor has major uncertainties. Anthropogenic greenhouse gas emissions (A), some of which are absorbed by the biosphere (B), lead to atmospheric concentrations (C), which produce enhanced radiative forcing (D). The climate system responds on both fast (E) and slow (F) time scales, resulting in coupled climate system warming (G). The climate warming will have regional variations in both temperature and precipitation (H) resulting in a sea level rise and other impacts (I).

5. Comparison of the Issues

Ozone layer depletion and the enhanced greenhouse effect are frequently linked in the public mind. Both are caused by the emission to the atmosphere of chemicals resulting from human activities. Direct measurements have shown that the atmospheric concentrations of CFCs (the main ozone depletor) and carbon dioxide (the main long-lived greenhouse gas) are increasing. Both CFCs and carbon dioxide have long lifetimes in the atmosphere (between 50 and 200 years). For CFCs, we know conclusively that human activities are the cause, since CFCs do not occur naturally. For carbon dioxide, there are very large natural cycles, but the scientific evidence is strong that the human emissions are the cause of the presently increasing concentrations.

Theories and complex computer models showing that: (i) increased CFC concentrations lead to reduced ozone concentrations; and (ii) increased carbon dioxide

on the control of substances that cause depletion of the ozone layer was relatively easy. Included in the agreement are processes of technology transfer so that the developing countries will be able to use ozone-friendly substances in refrigerators and other important areas. The Montreal Protocol also included provision for continuing scientific review and updating of targets. The London Amendment has been an example of how the process has worked to accelerate the elimination of the production of ozone-destroying compounds. It is important that activities continue to find even more ozone-friendly (and generally environmentally-friendly) compounds. At the same time, the CFC-ozone layer link demonstrates the importance of exercising extreme caution in introducing new substances to the Earth system. Since the impact on the ozone layer was not considered in the development and use of CFCs, impacts of other new chemicals may not include consideration of other environmental damage that we have not yet thought of.

Compare the CFC-ozone layer issue with that of carbon dioxide and the enhanced greenhouse effect. Carbon dioxide sources are everywhere; they result from processes fundamental to our global economy. At present, the developed countries are the major contributors but the contributions from the developing world are increasing more rapidly and, as they do, following the example set by the developed world, their emissions will sky-rocket. At the same time, the scientific case for global warming is weaker than that for ozone layer depletion. However, within the United Nations International Negotiating Committee, discussions have started towards a Framework Convention on Climate Change. Many countries have announced intentions of reducing their carbon dioxide and other greenhouse gas emissions. Canada has announced its intention of reducing net Canadian emissions to their 1990 level by the year 2000. How this is to be achieved has not yet been decided but it is one of the three elements of the National Action Strategy on Global Warming.

Since greenhouse gas concentrations have already gone up substantially, it is likely that the climate will warm over the next few decades. Further, it is unrealistic to think that global greenhouse gas emissions are going to be reduced by the amounts necessary to even stabilize present concentrations (that requires more than a 50% reduction globally). Hence, the atmospheric concentration of greenhouse gases will continue to rise, probably through the next century at least. It is therefore imperative that we understand how the climate will change and how to adapt to such change. For that reason, the other two elements of the National Action Strategy are adaptation and scientific research to reduce the uncertainty.

Scientific research to reduce the uncertainty on greenhouse gas induced warming must also be linked to understanding and eventually predicting the natural variations of climate. Through the Green Plan, a Climate Research Network is being developed, linking universities and government and industrial research groups across the country. The Climate Research Network will include activities to understand the oceans' role in climate, the impact of clouds, the changing water cycle (such as precipitation and evaporation on the prairies) and how these pieces fit together. A proposal for a Climate Integration and Prediction Centre, to be located in southwestern British Columbia, is being developed. These activities need to be closely linked with studies of the environmental and socio-economic impacts of climate change and have a direct path into development of Canadian policy.

6. Summary

Ozone-layer depletion and enhanced greenhouse effect climate warming are two important environmental issues. Our understanding of the former has greatly improved over the past decade and interna-

tional action has begun. For the latter, our understanding is less complete and international action will be very difficult. In spite of their major differences, these issues need to be linked. Both result from human intervention in natural processes by the emission of large quantities of substances into the atmosphere. Scientific understanding is essential to their solution. Both are global issues requiring global responses; countries cannot act alone nor can they ignore their responsibilities. In considering our responses to these and other environmental issues, it is important to keep in mind their linkages. In the past, the solution to one environmental problem caused another; we must not let this happen in the future.

Eve Savory: Thank you, Dr. McBean. I've been asked just to remind you that question cards are being distributed, and at the end of the session you may either come to the microphone to ask one of our speakers a question, or if you prefer, submit a written question.

Our next speaker this evening is Mr. Douglas Russell. He is the Director of Environment Canada's office which was established to develop Canada's position for the international negotiations on a Framework Convention on Climate Change. This office provides a focal point for Canada's involvement in the negotiations which includes consultations with provinces and industry, consumers and environmental groups and others. As Senior Policy Advisor for the Atmospheric Environment Service, Mr. Russell led the development of the atmospheric issue section of Canada's Green Plan, so you will know who to blame for that if you don't like it. He is a meteorologist by profession, and has worked as a weather forecaster, an oceanographic specialist and has taught meteorology in Toronto.

I would just like to add a personal note. I met Doug for the first time in New York City last week. I went down to cover the negotiations which were wrapping up; they were very tense, and for the first time I realized how important Canada was in those negotiations. It was one of a small group of nations meeting behind the scenes, desperately trying to get something on paper which our leaders could sign in Rio. And every morning, I would talk to Doug and I would say, "What time did they get to bed last night?" and he'd say, "About 4:30." So they were really working very hard. So, Doug.

Our Changing Climate: Building the Global Response

Thank you, Eve. Now it's not 4:30 a.m. yet, but if I fall asleep this evening, you'll know why!

It's a great pleasure to be here tonight to tell you about what I think is a very exciting development in international law



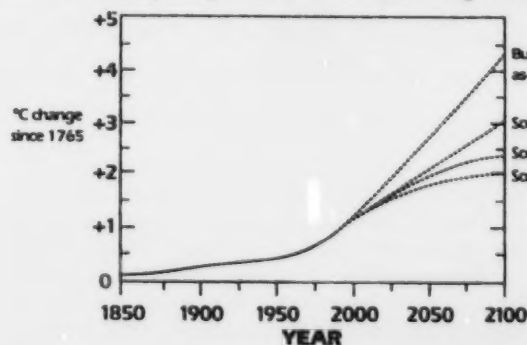
and a very exciting thing that's going to happen in Rio de Janeiro in a month's time.

But before I do, I'd like to review a bit. This morning, we had some very interesting talks at the Energy Forum which is happening here yesterday and today. This morning, I was particularly struck by a very, very eloquent and impassioned speech by Mr. Bill Wilson from the Assembly of First Nations who talked about the need in this country, in Canada, to have respect and respect leading to equity. And he talked about respect for each other as people and respect for other countries and indeed respect for our planet. And to a large extent, what we saw in the negotiations that have led to an agreement on climate change, actually is very much indicative of that spirit.

So with that as a background, I think there's a number of things I'd like to do tonight, and first of all I would like to talk a little bit about some of the issues that were important during these negotiations, give you a sense of what did go on behind the scenes to the extent that we can and, as well, to lay out what we achieved in these negotiations. And, I think, that taken as a package, when you see the whole thing together and not just little snippets from different media sources, then you'll realize that there is a commitment on behalf of the whole world to move in one direction. But it's a very difficult thing to explain in a short ten-second clip.

So I will start with some slides, and for those of you who were at the Energy Forum this morning, I apologize. I am going to have to use some of those same slides again, but bear with me and we will see what we have.

Gordon McBean talked earlier about the issue and the scientific evidence of this, and I think the conclusion is shown in Figure 1, from the 1988 Inter-Governmental Panel on Climate Change, held in Toronto. This sums it all up. We have to realize that global warming is not the latest environmental fad. It is not a political movement. It is not some sort of a new age holy grail or doomsday apocalyptic nightmare. It's real, and it's going to happen, even if we stop all greenhouse emissions right now!



(IPCC Report)

Figure 1: The Pace of Global Warming

Yet there are uncertainties, no doubt about it, and formulating responses in the face of uncertainty and in the face of very competing interests, it was one of the major challenges we faced in putting together this climate change convention. In Figure 2, I just want to give you a feel for the dimension of this issue. And what this figure shows is that it's always very tempting to say that if only the industrialized countries of the world would stop emissions of greenhouse gases, then this problem would be solved. But look at Canada. Canada produced 2 per cent of the overall world's total of human-made emissions of carbon dioxide. But on a per-capita basis, we're the second largest emitter in the world, after the United States.

Now look at all the other countries, and you see the trends that are going on. The trends are the important thing. This shows the changes from 1960 to 1987, a period of 27 years, and note in particular the size of the clouds over the USSR, China, India and even Latin America and Brazil. Compare those against the relative share of growth in the industrialized countries, you will see that those developed countries have actually declined in their share. Now it isn't because they are declining in their emissions; it's because others are catching up. At the same time the USSR has increased from 12 to 19 per cent; China, the country that sits on the world's largest coal reserves, increased from 2 to 11 per cent; India, from one to three per cent and others, mainly developing nations, from a total aggregate of about 16 per cent to 28 per cent.

There's a one-word explanation for this and it's the explanation that is part of the UNCED conference, and that word is 'development.' These countries have to develop. They have to have some sort of life for themselves, they have to put food on their tables and that is the real crux of this issue. This is why we came to negotiate this agreement. So it is not simply a matter of one large industrialized nation saying one thing, and another large industrialized nation or group of nations saying others. There is a whole dynamic need for sustainable development.

The cartoon in Figure 3 is really only the slightest of exaggerations. Again I go back to what Bill Wilson was talking about this morning, when he spoke of the imposition of certain values of certain people on other people and that's exactly the kind of thing that you have to consider in these north-south debates. Climate change was no different in our debate. We knew what the right thing to do was, we said "Well, we will have everybody do it the same way." Developing countries said, "Hold it now, you guys have had your time to develop, now it's our turn to develop, and let's have you help us try and avoid some of the mistakes you made in the past." That's really the crux of what this Forum is all about.

The balance in Figure 4 lists some of the key words that were at play during the negotiations on each side, if

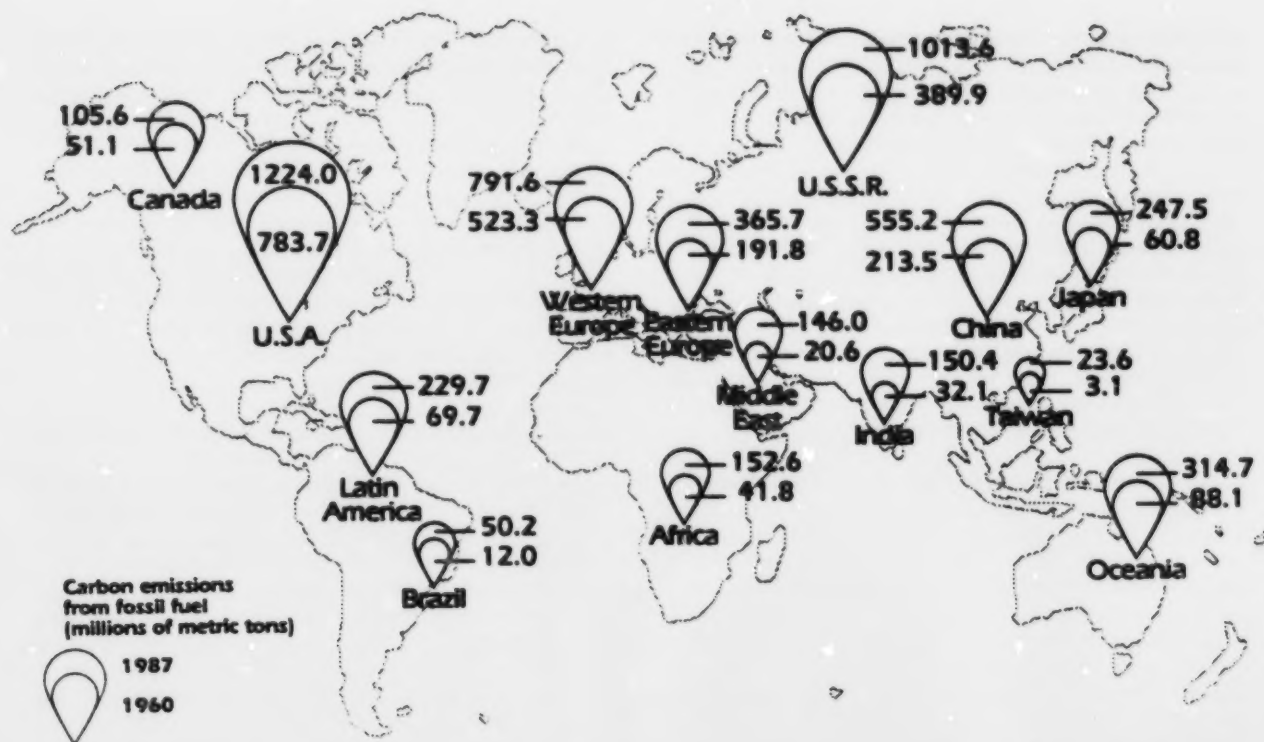


Figure 3: The Need for Global Action

you wish, of developed and developing countries. Often, on our side, we talked about trade competitiveness and we talked about the costs and we talked about limitation to consumption. Developing countries looked at it from a different perspective and talked about, "How are we going to develop? How are we going to have a lifestyle for ourselves? We need funding and technology transfer." Adaptation, population; these are issues that were on the lips of all the delegates at different times.

I think the important part is that when the gavel came down just after 6 o'clock on last Saturday afternoon, we had the negotiators from 147 nations willing to stand up and applaud a convention which managed to bridge those gaps, and they are very large gaps. So, enough of the problem. Let's start looking at solutions.

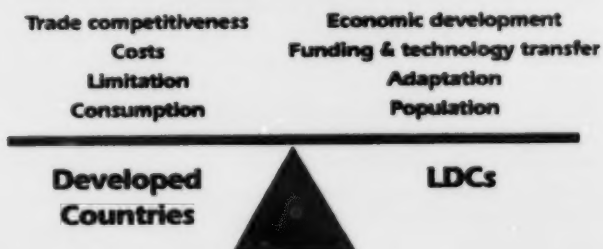


Figure 4: The North - South Dimension



Courtesy: Scott Wills, BCS Newsletter

Figure 3: Global Warming in an Unequal World

How do you attack the problem of global warming? How do you find a solution? Three aspects of it have been followed in Canada and throughout most of the world. First, we have to get everybody in the world moving in the same direction; that's what this international treaty, this international convention which, hopefully, will be signed at Rio will do. Second, we must back that up with national action. Action plans, not rhetoric, but actual things that are going on. This is what the convention makes countries do: it legally binds

countries to announce what actions they are taking and how they are going about solving this problem. Finally, it all comes down to each and every one of us: our individual actions, the choices we make in our daily lives, as to how we are going to address this problem. It's up to each of us to recognize our own responsibilities.

Figure 5 shows the pace at which global warming negotiations have taken place, and how far we have come in a short period of time. Compare this to other international treaties, such as the Law of the Sea, which was some ten years in negotiations, particularly if you consider that our first meeting amongst the intergovernmental negotiating committees was in February 1991 in Washington, just fifteen months ago. Subsequently, we've held sessions in various other parts of the world, in Geneva and New York, but probably one of the most striking was the one we held in Nairobi, where all the negotiators saw, first hand, the special problems that developing countries have. That was probably a spiritual turnaround for a number of people, who actually got a feel for what it is like in developing countries, and what serious problems they face.

But each of these is a major building block. What did we learn from all these various meetings that have taken place? We've learned how to negotiate; we've learned how to be patient, to realize that to achieve the achievable is a step-by-step approach, to try and get as much as possible from each step, but recognize that there is going to be a next step. And finally, how to work together to find that common ground. And I think this is a very important aspect that you have to keep in mind when you are dealing in these negotiations.

What do the results of this convention look like? Well, I can tell you about it, but unfortunately I can't show you. I don't have copies of it here, because we only finished them last Saturday afternoon. But copies will be available and I will certainly try and get them into the Proceedings of this conference. I am sure you will hear more about it during the UNCED conference next month.

Basically, the convention consists of three sections: one is a preamble that takes a look at the framework in which this whole thing would fit, including some principles and some general obligations. Then we

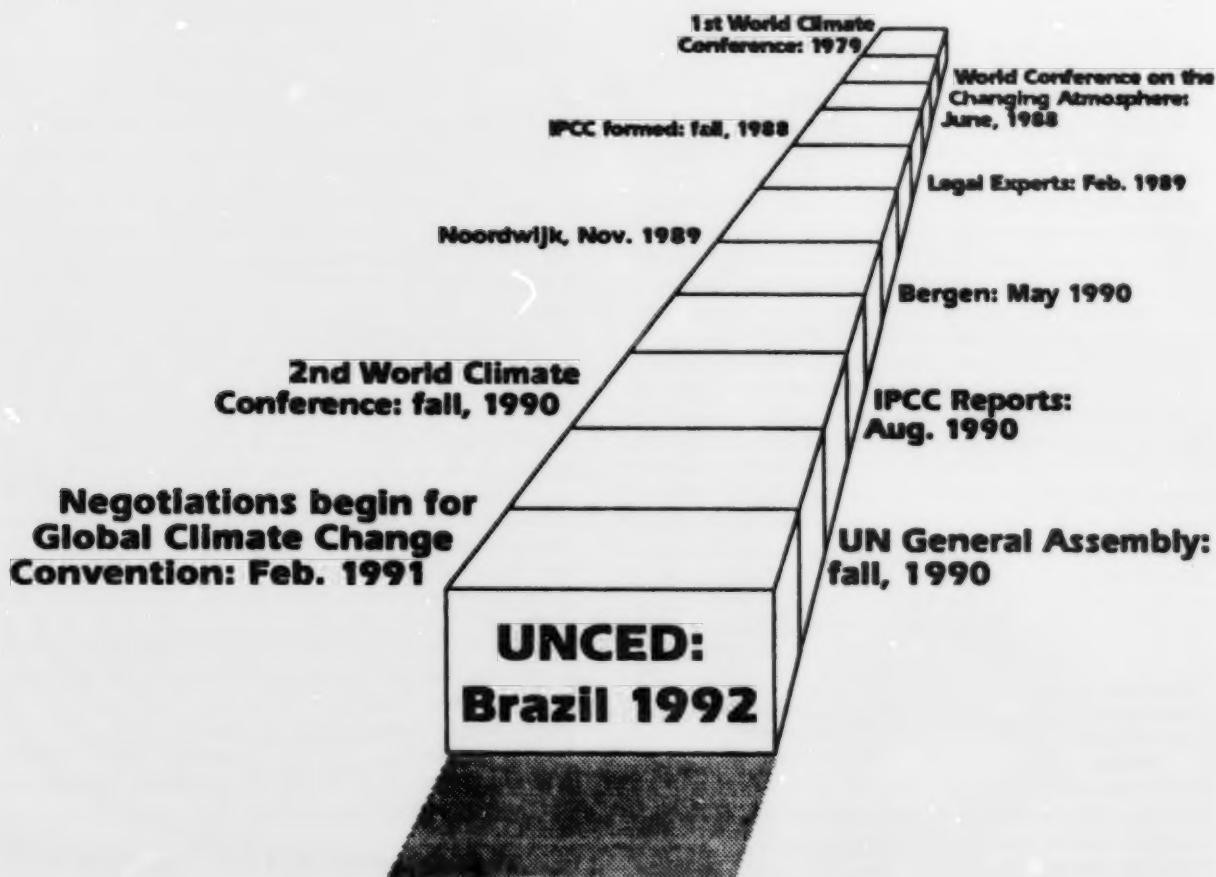


Figure 5: Building Momentum for Global Action

look at the key section, which is on commitments. What are all the countries committing to do both on reducing emissions and on enhancing sinks? Funding is a key issue that was finally resolved at 5:30 last Friday.

Second, how do you deal with those countries facing immediate threats from certain aspects of global warming, such as sea-level rises and inundation? Some Countries that you and I have never heard of, only a metre or so above sea-level, countries, whose existence is actually threatened.

Finally, the last part of the convention deals with what is not normally reported on in the media and not normally reported on by a number of people because it's not sexy, it's not the exciting part, but it is the part that makes things work. It is the mechanisms of how is this going to work. How is this going to be put in place? How does this process actually go? And in this there are provisions for probably the strongest institutions, the strongest kind of process that we have seen in international law to date, including science and observation, compliance and review and again on how you handle the disbursements for funding and technology.

Canada went in with a lot of objectives for this convention, which were developed through a very innovative process. We invited people in to discuss our negotiating positions, as part of an advisory committee which met regularly throughout the negotiations. It represents as broad a spectrum of Canadians as possible. The committee also represented the federal/provincial aspects of provinces and territories, and prior to each negotiating sessions, we wrote separate documents which went to the federal cabinet. Our mandate was approved each and every time, based on these consultations.

We made a very clear effort to do this and it paid off, because we were considered by the global community to be moderates. We found ourselves in the middle of the pack on most issues, and that allowed us to play the kind of bridge-building role that Eve alluded to earlier, the kind of role that Canada normally plays in international negotiations, and the role that is expected of Canada.

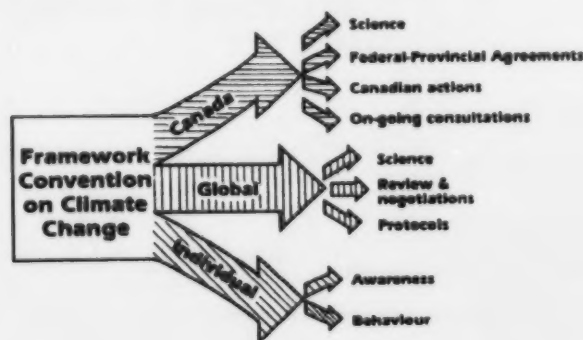


Figure 6: Beyond Brazil '92

What follows is a short check list of our objectives to give you an idea of what's in the convention.

(1) First, we wanted a long-term goal that would protect the climate system. The overall objective of the convention does exactly that; it stabilizes concentrations of greenhouse gases in the atmosphere at a level that would prevent dangerous and anthropogenic emissions, or dangerous human-induced damage to the climate system. It does it in a time frame that would allow people and ecosystems to adapt. That is the overall objective of the convention written into Law Article 2.

(2) Probably the most important aspect of a convention, which is sometimes lost in the media presentations, is that it has to be global. All countries must be working together and, as I indicated, we had 147 countries stand up and applaud at the end of the day for the adoption of the negotiated text, which will be now sent to Rio for heads of government to sign. Developed and key developing countries such as Brazil, China and India, all expressed support for this convention. On the developed country side, the United States favours this convention and they will sign. A comprehensive approach was the second thing we wanted.

(3) We wanted to make sure that we didn't lose sight of the fact that there is more than just carbon dioxide in this Greenhouse issue. Other gases are involved, and many developed countries only wanted to deal with carbon dioxide and let other emissions ride. Canada wanted to do it in a comprehensive manner, to deal with the totality of all greenhouse gas concerns. That is enshrined in the actual convention, and from day one, it encourages countries to take actions on all fronts.

(4) We wanted it to be flexible and phased. It is that. It sets realistic time frames and there will be regular reviews. The effectiveness of this convention will be reviewed at least twice before the end of this decade and maybe more frequently.

The key issue that has been reported on is targets and schedules; Canada went in looking for a convention which would have specific legally-binding targets and schedules. The convention does not have that; I don't think any legal interpretation would permit those kinds of specific binding targets and schedules. However, it does lay it out as a guideline and certainly the political impetus is there. Our interpretation is that it will be up to the citizens of each country to continue pressuring governments through this process of clear and open transparent policy-making, to ensure that countries publicly announce their targets and the guidelines that they are committed to.

(5) A commitment to action; and that is exactly what this is. Within six months of entry into force of this convention, all developed countries must have a cli-

mate program in place and be reporting on exactly how far it will take them towards the convention guidelines on reducing the growth of emissions.

(6) Best available science; there are strong institutions to ensure that the best available science is fed in to the conference of the parties as they make their decisions on this approach.

(7) An ongoing review and update. As I mentioned, the preparations begin for continued negotiations the day after Rio closes, and will continue throughout the summer and onward, probably at a fairly rapid pace and that's a very encouraging aspect.

(8) It adopts a precautionary approach in the face of scientific uncertainty. You do not remain inactive, you do encourage actions. That is written in as a principle of the convention.

(9) And it encourages public awareness and public education, so it gets down to the role of individuals all around the globe. So they know, people know exactly what it is, what the consequences are and how we go about it. It would encourage the use of economic instruments and regional approaches.

In conclusion, as time runs out on me, **Figure 6** depicts this ongoing process. It's a positive process, it's a positive first step in the fight against global warming which will have to take place in Canada after the Brazil conference: to look at science, to look at federal-provincial agreements, to look at Canadian actions and ongoing consultations. Globally, again, the issues are; science, continuous review and looking at how things are working. But finally, it comes down to each and every one of us; to change the way we look at this issue.

That's the convention; I think it's a good one. It starts the ball rolling. It has all nations of the world moving in the right direction and in the same direction.

Thank you.

Eve Savory: Thank you, Doug. I think our next speaker is probably going to challenge some of your assertions in his statement. He is what we journalists refer to as the balance in the program.

Dr. Brian O'Brien is head of the firm, Brian J. O'Brien and Associates, which is an environmental consulting firm in Australia. His clients include Australian state and local government departments and agencies, private sector companies and the Australian and New Zealand Environmental Council. He's been a professor of physics, astronomy and space science at Universities in Iowa, Texas and Sydney. He also served

as director and chairman of the Environmental Protection Authority in Western Australia.

Dr. O'Brien was a principal in the design of six experiments deployed on the moon during the Apollo program, for which he was awarded the Nassau medal for exceptional scientific achievement.

He has published several hundred scientific papers and has many inventions and discoveries to his credit. He is here, I would say, as a tilter at windmills and his paper is entitled *The Greenhouse Holy War*, which suggests what he's going to talk about.

Please welcome Dr. Brian O'Brien.



Thank you, Eve. Good evening, ladies and gentlemen. I am in a rather curious position here tonight because I don't want to provoke your anger, but I do want to provoke you to thought. I think probably I've been assigned this role tonight because I don't live in Canada, and I'll be leaving the country again fairly quickly. But somebody has to tell the community that the emperor has no clothes; or if he has clothes, they are not quite what they have been perceived to be.

Preamble

I am going to talk about the science of greenhouse gases but I'm going to talk in very general terms, because I don't really disagree with what the previous speakers have said about the science. The science is pretty well accepted. It's the emphasis that's placed on the individual issues and the consequences of that emphasis that I disagree with. Basically, my theme, which has been verified by the previous speaker, is that the pace of this agreement has been unprecedented, and this pace was set in the emotion-laden atmosphere of the 1988 Toronto conference and it really hasn't changed since, in spite of more reassuring scientific research and more emphasis on uncertainties.

The agenda was set in 1988. I am going to talk about the science; but I am going to talk about the science in a way that's coloured by my personality and my prejudices; I freely admit that. I am basically a fairly fat, happy grandfather. And all of those issues are fairly relevant to how you interpret impending doom and gloom for our planet.

The Greenhouse Holy War

Introduction

Before countries which are vast, thinly-populated and richly endowed in under-utilised natural resources embrace a popular environmental cause such as greenhouse and climate change, they have a moral responsibility to understand the issue. Canada and Australia are both such countries.

Our two countries must understand the issue in its totality, not merely in parts.

And in the Greenhouse Gas Emission Issue (Greenhouse), which is certainly the most extraordinary outbreak of popular sentiment and sloppy science I have encountered in my 40 years of scientific research, the totality is both complex and very simple. But sadly, it is seldom articulated.

Greenhouse began as a scientific issue but has become a crusade and a Holy War. It is based on a surrogate religion that appeals for many different reasons to many different elements in the community. It is the supreme case of the politicization of environmentalism.

Before examining the totality of greenhouse, let me make several points clear.

There is a natural greenhouse effect, which keeps the planet earth comfortably warmer than it would be without the natural greenhouse gases, principally water vapour, carbon dioxide and methane. These natural greenhouse gases, by absorbing infrared radiation, force some 148 watts m^{-2} into the planetary system, warming the earth by some 33°C to an average temperature of about 15°C instead of a very cold -18°C.

There is also a man-made or cultural greenhouse effect, caused by increasing concentrations of greenhouse gases, some natural like carbon dioxide, and some artificial like CFCs, the chlorofluorocarbons. In 50 years or so, this cultural greenhouse effect, which is what the fuss is about because it is man-made, will cause a forcing of some 4 watts m^{-2} . The resultant increase in global temperature is variously estimated at between about 1.5°C and 4.5°C (IPCC 1990).

That much is the scientific conclusion of the Intergovernmental Panel on Climate Change (IPCC) in their 1990 and 1992 reports.

It is important to understand that in spite of an enormous amount of research and reports there are only two fundamental facts in greenhouse science:

1. certain gases such as water vapour and carbon dioxide absorb infrared radiation and thus 'force' thermal energy back into the planetary thermal system, and

2. concentrations of some such gases are increasing, and parts of the increases are due to human activity.

The greenhouse theorists, such as in the IPCC, then add many assumptions to these facts, and the result is popular greenhouse 'science.'

The greenhouse extremists of a few years ago used to claim a direct cause and effect relation, between

increasing concentrations of greenhouse gases, such as carbon dioxide, causing the earth to warm. The 'correlation' of Figure 1 was regarded as such evidence.

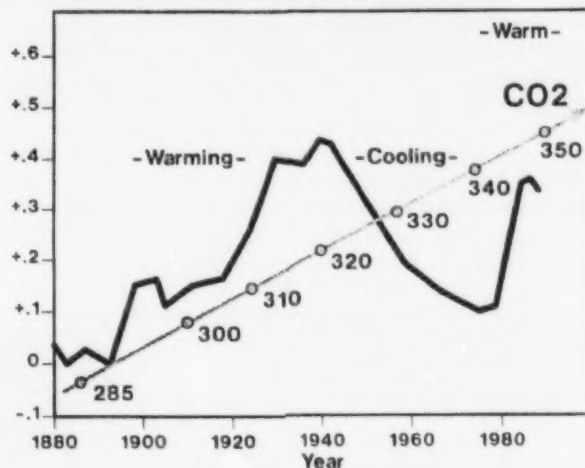


Figure 1: The 'Correlation' of Global Temperatures and Carbon Dioxide Concentrations

Since the IPCC report of 1990, such 'correlation' has been discredited. A host of 'correlations' of completely unrelated phenomena show far closer apparent coupling than does greenhouse. I've shown one of my favourites, because I am both a Councillor of the National Trust and a consultant for the iron-ore industry, in Figure 2.

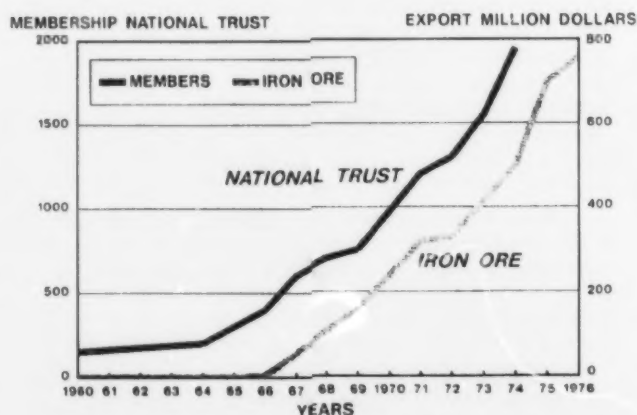


Figure 2: The Spurious Correlation Between National Trust of Western Australia Annual Membership and Iron Ore Exports Approximately Two Years Later

I am willing to accept the consensus climate 'predictions', or more correctly, 'scenarios,' as the best that can be done at present. The scientists involved know, and often state, just how uncertain those scenarios are. Unfortunately, many tend not to convey the uncertainties as forcibly as they should.

But greenhouse science has long been overwhelmed by greenhouse psychology.

One can freely acknowledge that greenhouse psychology has caused some benefits, like greater community awareness of the need for energy efficiency. Similar effects were caused by the hip-pocket impacts of the OPEC oil crises in 1973 and 1979, when the USA communities were moved to reduce speed limits to 50 miles per hour, and other like measures.

But the greenhouse phenomenon is also causing negative effects, particularly on vast, thinly-populated countries richly-endowed in minerals and natural resources that are presently under-utilised. I refer particularly to Australia, and potentially Canada.

In Australia, it has produced a negativism, an attitude that various things should not be done QUOTE because of the greenhouse effect UNQUOTE. A new power station should not be built, or a coastal development should not be built, or a woodchip industry should not be established, because of the so-called greenhouse effect. There is a negative image weighing against new industry and shading the odds against it, if such labelling, always unquantified, can be attached to it.

Worst of all, in my opinion, the greenhouse crusade is producing schoolchildren who are indoctrinated with images of impending doom. At the stage of their life when children should be rejoicing in the beauties of nature, and their teachers should be helping them understand such natural magic as Raleigh scattering in a sunset, or the delightful adaptations of plants to their environments, they are worried about pollution, and litter, and doom and gloom in the future. Such topics of gloom are much easier to teach, just as they are much easier for the media to report. We accept that 'good news' will not be reported, but I fail to see why it should not at least reach the schools.

I should mention in passing that I do not believe that many industries appreciate just how massive a change this indoctrination of children with doom and gloom will cause when they join the work force. Industry may think that at present it is having unnecessary difficulties with Young Turks in environmental agencies. They may be more vigorous in pursuit of environmental godliness than their older, more pragmatic or balanced superiors.

In ten years time, those Young Turks will be in senior positions. Furthermore, the new young Turks will be the whole new generation brought up on a diet of environmental gloom and doom, of pending disasters of greenhouse or biodiversity or whatever.

If industrialists think that they are presently burdened by Governments with excessive environmental constraints, my prediction is that they ain't seen nuthin'

yet. UNLESS, of course, more rational approaches and more scientific approaches replace or at least balance the present religious fervour of environmental education.

Therefore, it is essential that countries like Australia, and if you will, Canada, thoroughly understand the greenhouse phenomenon in its totality (O'Brien, 1990a). The physical actualities of climate change are only a part of it.

The Psychology of Greenhouse

Greenhouse meets many psychological needs.

Weather is an eternally popular topic of conversation, and unusual weather even more so. Greenhouse can be used as an excuse for unusual weather. It makes party conversation so much more intellectual, and is a good topic from which further chat-ups flow.

'Unusual' weather is always of public concern. There is not a great gulf between a joking comment that greenhouse is a cause of such effects and a gradual wonder whether this might be so. Media reports often encourage such comments. Repetition breeds repetition.

There is a human desire to understand the causes of vast natural processes that affect us, like the weather. Primitive tribes and modern civilisations alike attribute complex causes to simple gods whom they can easily visualise and then appease. Greenhouse is such a god. You don't need to understand its mysteries - simply invoke and appease it.

Furthermore, people like dramas with villains and victims. Greenhouse has both, with images of poverty-stricken people in Bangladesh fleeing before rising sea-levels caused by capitalist countries indulging themselves in motor cars, power stations and all their trappings of wealth.

People like to feel they are doing something to relieve injustice and inequities in the world. How many times have Canadians been told that their per capita production of greenhouse gases is second highest, or some such number, in the world, and encouraged to feel guilty about it. As if the very notion is relevant, or as if the whole world consists of equal units of land and equal units of climate stresses and equal everything, in a drab and depressing uniformity of spiritless nothingness.

People like to feel they are helping the future. Recycling drives, such as were popular during the Second World War, come and go with varying degrees of popular support, often with little attention to their economic efficiency. The extra effort of sorting rubbish makes people feel they have done a good thing. So it is with greenhouse. People are urged to turn off unnecessary lights, and if they are told they are helping to stop

climate change and to save our planet, they obviously feel a greater sense of self-satisfaction than if they are told merely to save an abstract concept like energy.

There can be little doubt that greenhouse delivered to opponents of growth and development a wonderful psychological boost. At last, their forebodings that things were getting worse and heading for disaster seemed to have a scientific basis people could relate to.

Furthermore, combating greenhouse requires promotion of efficient use of resources, a guarantee of popularity.

Such psychological attractions of greenhouse meant that it could be heavily promoted, be widely accepted and be respectable. Its scientific complexity ensured that it could be preached as a religion, with a satisfactory shroud of mystery beyond questioning.

What is frightening is that some scientists have been caught up by the excitement of the greenhouse process, and by the warm inner glow they get from the feeling that they are helping the world unite to save it from itself. Their scientific objectivity may be at risk.

The Toronto Conference, The Old Testament and The First Commandment

The Greenhouse Holy War has a Bible. The Old Testament is the statement from the Toronto Conference in June, 1988.

I make the association of Greenhouse and religion, and make reference to Biblical analogy, with complete respect and without intending any offence.

Some may question whether it is fair to the people at that Conference to speak of the Toronto statement in religious terms, so the opening statement is quoted to let individuals make their own judgement:

"...Humanity is conducting an unintended, uncontrolled, globally pervasive experiment whose ultimate consequence could be second only to a global nuclear war..." (Summary of the conference Statement, page 292 of the Proceedings of the World conference on the Changing Atmosphere, Toronto, June 27-30, 1988).

The religion certainly has its first commandment, carved in stone at Toronto and impregnable to later assaults by scientific findings such as those of the IPCC. The commandment was given the name of the Toronto target, viz:

"Thou shalt reduce carbon dioxide emissions by approximately 20% of 1988 levels by the year 2005 as an initial global goal."

This Toronto Target, the 20% figure, has been widely promoted. It has been adopted by several coun-

tries as a policy. Yet few stop to consider its origin, and whether it has any credibility at all.

In fact, the Toronto Target of 20%:

- has no scientific basis, and never did have,
- was a number plucked from thin air at Toronto,
- was derived at a time when greenhouse fears were exaggerated, but has not been changed to take account of four more years of scientific findings, e.g., IPCC,
- must apply forever, to be effective, and
- is scientific nonsense anyway, because the uncertainties as to carbon dioxide processes are some ten times larger, about 200%.

Indeed, in an analysis before the Australian Industry Commission Inquiry into the Costs and Benefits of Reducing Greenhouse Gas Emissions, O'Brien (1991) listed a total of eleven scientific flaws in the Toronto Target, largely by quoting from IPCC and by noting various unstated assumptions, e.g., that any climate change is necessarily bad. These are listed in Table 1.

The Toronto Target has no scientific credibility. It is purely a political religious target.

Such targets, or any such goals for any process whatsoever, such as immigration levels or popular growth or economic growth, can be adopted by governments as part of a democratic process **provided they know:**

- **why they are doing it, and**
- **what are the costs and benefits.**

In Australia, the Toronto target was undoubtedly chosen for political reasons by various governments.

As to its cost, an independent assessment by the Industries Commission is that it would cost Australia some \$6 billion annually.

[The notes above were written when there still seemed a possibility that the Rio Convention might adopt the Toronto Target. Now that it seems more likely that only 'processes' will be adopted, it is going to be even more difficult, and probably impossible, to use science to argue for more rationality in the future. However, the flaws in the First Commandment must be reiterated, because it is only a matter of time before it is regurgitated, probably in a fuzzier form that will be harder to analyze.]

IPCC and the New Testament

In greenhouse, there is no doubt that in 1988, when the Toronto Target was set, the reason *why?* was an attempt to save the world, particularly from the easily-visualised threat of rising sea levels.

In the United Nations, in October 1987, President Gayoom of the Maldives 'galvanised' delegates with talk

Table 1: The Eleven Flaws in the Toronto Target

1. **The Modelling Flaw** is the usual assumption that the only scientific uncertainties in climate change are the dozens of major uncertainties of predictions, and that these will be worked out in time by the scientists.
2. **The Panglossian Flaw** arises through the unspoken and seldom-acknowledged assumption that the present-day climate is the best of all possible worlds, an assumption likely to be questioned, for example, by Queensland immigrants from Melbourne. There are known and acknowledged advantages to some climate change.
3. **The Toronto Flaw** is the complete lack of scientific justification for the original Toronto target of 20%, being merely a number plucked from thin air in 1988.
4. **The Postponing Flaw** arises because the latest scientific findings have now 'postponed' by 150 years the onset of the worst fears at Toronto in 1988 about the worst effects.
5. **The Nexus Flaw** arises from the lack of one-to-one correspondence between resources efficiency and greenhouse emissions. Consequently, the tacit policy that greenhouse worries will necessarily lead to increased energy efficiency is partly a logical nonsense.
6. **The Jindalee Flaw** is the rubbery and unusual hidden nature of time scales used in Greenhouse. As an example, the relative strengths of the two greenhouse gases, methane and carbon dioxide, on a gram-for-gram basis, are between 63:1 and 9:1, depending on whether one considers a 20-year or a 500-year time horizon. Consequently, any economic emphasis towards individual gases must know which time frame has been applied. This class of flaws also includes the difficulty of predicting technology and society in 60 years time.
7. **The Inhomogeneity Flaws** of this inquiry exist because of the hidden assumption that Australia, in thinking globally and acting locally, should ignore its natural attributes and pursue a greenhouse policy as if the planet was homogeneous and isotropic. This is demonstrably absurd within Australia. It also ignores the special geographic location of Australia as a remote, resource-rich island surrounded by thousands of kilometres of carbon dioxide-consuming oceans.
8. **The Micawber Flaw** assumes that other new greenhouse savings measures, such as widespread nuclear power and renewable energy resources, will turn up. The unstated consequence of the Toronto Target is that after 2005, greenhouse emissions must never increase, ever again.
9. **The Hiatus Flaw** induces a false complacency that attempts to meet the Toronto target have more long-term significance than they warrant. This flaw neglects the fact that greenhouse emissions can be reduced once only by changes in lifestyles and engineering practices that remove past extravagances in resource use. It can induce a false sense of complacency about the feasibility of achieving the Toronto target by 2005, and ignores the reality of the unstated Micawber Flaw.
10. **The Resilience Flaw** is the failure to recognize the proven resilience of living systems to the extreme ranges and the extreme changes in the natural climate and weather systems in which they evolved.
11. **The Hubris Flaw** is the possible flaw of insolence and arrogant self-confidence that can arise in policies and decisions when a single group of scientists has a monopoly on providing high-profile advice to policy-makers, in force for several years and resistant to new, external ideas. The Hubris Flaw can cause synergistic effects in government funding dedicated to encapsulated policies frozen in old mindsets.

of his island nation being drowned by rising sea levels. Much of the Australian political talk, and the public promotion of greenhouse, particularly in 1988 but even as recently as 1990, was about drowning island nations. A cartoon of the Sydney Opera House being submerged by rising seas was widely promoted.

So it is as well to compare the scientific predictions about sea level rises, in 1988 versus now. The results are shown in Figures 3 and 4.

The Toronto statement of 1988 predicted future sea level rises **probably on the order of 30 cm but could be as much as 150 cm by the middle of the next century.**

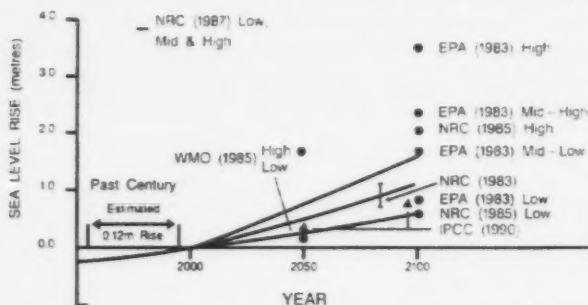


Figure 3: Various Estimates of Future Sea Level Rise

Most Australian government policies were set in 1988 and 1989, before the New Testament of the Intergovernmental Panel on Climate Change (IPCC) appeared. Others on this panel can comment on Canadian policies.

The IPCC Working Group 1 (Science) statement of 1990 said that for a Business as Usual emissions scenario, we faced a rise of **about 20 cm in global mean sea level by 2030, and 65 cm by the end of the next century.**

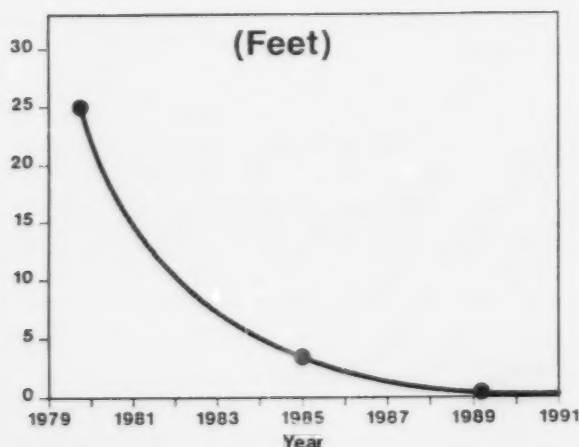


Figure 4: Predicted Sea Level Rise vs Prediction Date

The 150 cm rise in sea level feared at Toronto as 'possible' in 50 years has been 'postponed' by another century or more. In the four-page summary statement of the IPCC in January, 1992, from Guangzhou, China, there was not even a mention of sea levels.

Alas, the lesson that the **urgency** of greenhouse has been postponed by the new IPCC findings seems often to be overlooked (O'Brien 1990a). The enormous international, national and provincial bureaucratic machines of climate change grind inexorably on.

One merely has to look at the IPCC and UNCED organisation charts to know that bureaucracy is running rampant. How many Greenhouse advisory committees, or grants committees or conventions are there?

It is the **greenhouse process** of international negotiations, not climate change at all, that dominates.

Furthermore, there is documentary evidence that there was a 1988 mindset on the **largest possible changes**, in the order of metres, which persisted into the 1990 deliberations of Working Group 2 (Impacts) of IPCC (O'Brien 1990b). This makes the updated scientific findings even more distant from the policy makers.

Uncertainties in Predictions

The Major Conclusions from IPCC at Guangzhou (1992) repeated the 1990 conclusions and cautions:

- there are many uncertainties in our predictions (of climate change), particularly in regard to the timing, magnitude and regional patterns of climate change, due to our incomplete understanding, and
- the size of this (global) warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability, and
- the unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more. It may be noted that much the same was said by IPCC two years earlier; so the decade is 'stretching.'

Nobody can doubt that greenhouse predictions are uncertain at best. There is no need to repeat here detailed discussions of the causes of such uncertainties, but they include:

- a vast 'missing sink' of carbon dioxide,
- uncertainties of some 200% in gas processes,
- effects of clouds - heating and/or cooling,
- effects of aerosols - heating and/or cooling,
- uncertainties about oceans,
- natural effects, e.g., previous thaws of Ice Ages,
- imperfect computer models, and internal inconsistencies, and
- responsibility disclaimers for predictions, etc., etc.

Yet at greenhouse meeting after greenhouse meeting, there are presentations made of so-called predictions of effects of regional rainfalls, or temperatures. Vancouver Island is a magic oasis in Canada's rugged winter climate. Yet computer models for greenhouse cannot discriminate it from Lake Louise or Calgary.

One sad side-effect of concentration of research on greenhouse is that vital research into effects like El Niño are neglected. Severe droughts and floods in eastern Australia have been proved to be associated with El Niño and its inverse, with cycles of several years. Yet greenhouse climate models neglect El Niño.

The farmers of eastern Australia will have perhaps half-a-dozen devastating floods and three or four horrifying droughts while greenhouse watchers are waiting for the sea-level to rise by 20 or 30 cm!

The word 'science' comes from the Latin 'scientia' - knowledge. One of these days, scientists, who are the only ones who appreciate how large these greenhouse uncertainties are, and how immediate the El Niño effects are, must once again rejoice in imparting knowledge, not fear.

They may then, of course, lose their research funds, provided by pragmatic politicians.

Non-Zero Catastrophe Probability

There is one dominant reason given by greenhouse disciples as to why action should be taken now to reduce greenhouse emissions. It derives from, and has strong overtones of religious debate about whether God exists.

The argument runs that if the effect (God or greenhouse) is real, then the belief and actions are essential. If the effect is not real, then no harm is done.

A fascinating example of such fervour was a submission by the Australian Department of Environment (DASETT) to the Industry Commission Inquiry. DASETT used the notion of a non-zero probability catastrophe. The ideology is that in the case of a 'catastrophe' such as greenhouse, the onus of proof is reversed, and it is the responsibility of sceptics to prove that the predicted harm will NOT occur.

Advocates of such a philosophy attempt to justify it as insurance. But instead of actuaries, it has zealots. In any case, the philosophy is offensive to scientists, or it should be.

True science cannot work with such an ideology, which does not tolerate debate, but false sciences can thrive on it. It must be abandoned, politically attractive as it may seem.

Curiously enough, at least in Australia, the forces of industry seem to largely accept greenhouse predic-

tions and policies as realities, and merely quarrel with government as to the detailed impacts of their policies, such as the costs of imposing targets, or carbon taxes or whatever. There is now a thriving industry of economists and lawyers investigating Greenhouse hypotheticals!

Industry uses its economic expertise to calculate such costs. Some accept the fears in what I find to be a curious and almost childlike faith in what they are told will be climate change. And by doing so, and fussing about consequences of policies rather than credibility of policies, they actually lend credibility to greenhouse, through the most extraordinary process of the inverted pyramid of Figure 5.

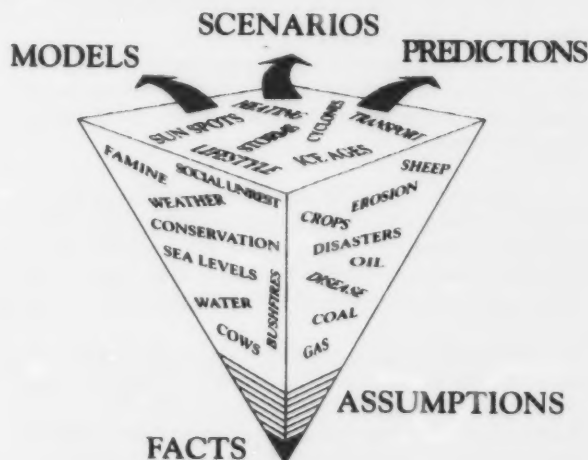


Figure 5: The Inverted Pyramid of Greenhouse

Robert White, President of the US National Academy of Engineering, cautioned in April 1989:

"Whether we in the scientific community like it or not, we have awakened the political beast ... We are confronted with an inverted pyramid of knowledge. A huge and growing mass of proposals for policy action is balanced upon a handful of real facts."

I have attempted to sketch this effect in Figure 5. What is happening is that people are judging the importance of greenhouse from the size of the Inverted Pyramid, and by such happenings as 20,000 people attending the Rio Conference.

But the number of facts remains at just two.

Even if one accepts all the IPCC reports, and neglects such criticism as temperature data being biased by urban heat islands etc., the inescapable conclusion is that the alarmist urgency of Toronto is unjustified. Greenhouse has been 'postponed.'

There should be recognition that there is time to let policies first catch up and then proceed in step with improved scientific knowledge. But the New Testament of the IPCC, with all its uncertainties, has not been promoted with the vigour of the Toronto testament.

The Old Testament prophets of Toronto did not dwell on uncertainty as they thundered their messages of doom. The New Testament scientists of IPCC Working Group 1, honestly emphasising scientific uncertainties, sound like mere wimps and are little heeded. And the First Commandment is questioned at one's peril. Developed nations seem relieved that they can point to the United States as the infidel who continues to refuse to believe in the magic 20 percent target.

The Apocalyptic Visions

In the fervour of the Toronto conference in 1988 there was an intense sense of urgency, demonstrated throughout the record of the proceedings (WMO Report No. 710, 1989).

Although scientific predictions of future rises in sea level were gradually being refined to smaller values (Figures 3 and 4), the older numbers of a metre or two were impressed as mindsets. They were also widely promoted in the media and UN deliberations.

Such apocalyptic visions have given greenhouse, the IPCC discussions and Rio Conference a false sense of urgency that sweeps science aside. It is of no importance to Rio negotiations that IPCC predicts that the worst sea-level rises of 1.5 metres most feared at Toronto will not occur until a century or two later (Houghton et al., 1990; O'Brien 1990a). The First Testament predicts imminent Apocalypse, and disciples love it.

Some IPCC negotiators boast that a Climate Change Convention is being achieved so much more quickly than, say, the Law of the Sea Convention.

But if challenged, they may deny that there is undue haste.

The proof of haste is easily seen in the mindsets about sea levels (O'Brien 1990b).

But it is also easily seen even without invoking any science at all, but just examining the juggernaut processes of IPCC moving inexorably towards a Climate Change Convention at Rio in June 1992 even before IPCC reports were complete. The Rio Convention was being planned to cope with climate change before the scientific predictions of climate change were made by the enormous international scientific efforts of IPCC. Heaven help anyone who might have suggested that Rio be postponed. The Brundtland Commission findings on sustainable development, not IPCC, made Rio an inevitable meeting, not about climate change, but about the paradoxes of environment and development.

The road to Rio is easily seen in the very structure and methodology of IPCC itself. There were three Working Groups:

- WG1 (Science) predicted future climates,
- WG2 (Impacts) was to predict the impact of the predicted climates, and
- WG3 (Response) was to plan policies to cope with the predicted impacts of the predicted future climates.

In an ideal world, or even in a rational one, WG1 should have reported first, then WG2 should have used WG1's predicted climate to predict impacts. WG3 should then have developed policies to cope with the impacts predicted by WG2.

But in the real, greenhouse world, all three groups began work at the same time, on a burdensome urgent mission to have results ready for Rio in June, 1992, the time for St. John's Revelations, Chapter 7.

At the gatherings in Rio, there will be a unifying sense of euphoria that 147 or so nations have come together in peace to discuss climate change. In fact, the scientific details of climate change have become largely irrelevant.

The agenda will be dominated by issues of developing nations, of international equity, of pseudo-scientific economic jargon of carbon taxes and greenhouse trading rights, of technological transfer, etc. Greenhouse is offering fresh fields and pastures new for a host of political economists and international lawyers, offering sage advice to the vast band of environmental devotees, aspiring and practising politicians and social engineers.

A physical scientist interested in accurate predictions of actual climate change will be truly a prophet wandering in the wilderness. But his voice will not be heard at Rio.

In Figure 6, I have sketched the components of the Greenhouse Holy War. Science has now only a very small slice of the pie.

Fine. Let the feel-good conference take place in all the comfort-giving of a religious event. The gathering may well help improve the well-being of many, and lead to greater international peace and goodwill.

But let nobody be under any illusion that the conference is based firmly on the physics foundations of greenhouse. Furthermore, when the conference is over and the euphoria is waning, all the tens of thousands of greenhouse disciples will return to their work places desperate for further missionary work, and eager to turn the messages they received into real-world and day-to-day doings. It will be difficult to resist them, and indeed some may embark on new crusades, such as biodiversity.

Old Testament - Toronto Statement
New Testament - IPCC Reports
First Commandment - Toronto 20%

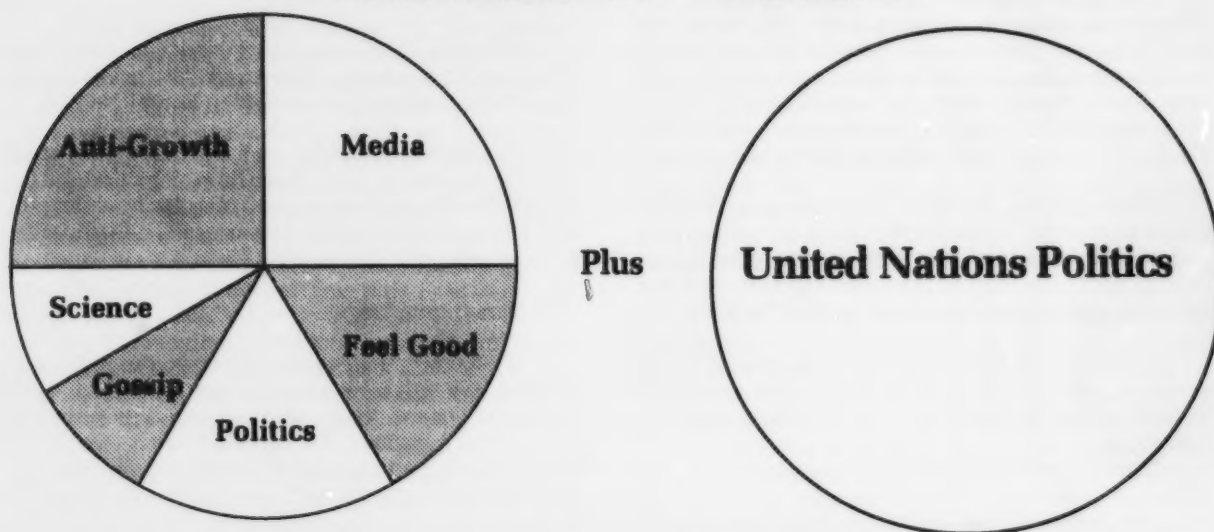


Figure 6: The Greenhouse Holy War: Its Factional Roots

Concluding Comments

Greenhouse policies for young, resource-rich, developing countries like Australia and Canada require even more discriminating and careful attention than policies for established giants like the USA or potential giants like China.

For a country as vast as Canada, containing a thinly-spread population, much of which has to confront long and bitter winters (except in climate islands like Victoria), to develop a greenhouse target as if the world was homogeneous and equal seems as foolish as the similar political mentality applied by strutting politicians in Australia.

Australia, too, is an island continent, surrounded by thousands of kilometres of oceans that devour carbon dioxide. It is resource-rich but thinly populated, mainly at the coastal edges. Yet the Toronto target is espoused, although with caveats.

Australia can probably do more to counter global climate change and acid rain by developing its resources, and then adding value to them by establishing refineries and downstream processing instead of shipping raw minerals to remote but polluted countries.

I have suggested that if Australia sold a few hundred million potbellied stoves to China, it could not only add value to its iron ore resources, but it could decrease global warming at the same time by increasing the

efficiency with which China burns 1.1 billion tonnes of coal annually.

But if it does so, its per capita contribution to global greenhouse will increase. The political figures may feel embarrassed on global stages such as at Rio in June, when they should feel proud and self-confident.

Although the dramatic urgency of greenhouse calls have been largely discredited, and claims exaggerated with science often proven to be sloppy, the fact remains that climate change is an important component for future strategic planning. Regardless of whether future climate changes are caused by combinations of El Niño or La Niña effects, by greenhouse, by solar-plasma couplings to terrestrial processes, by Milankovitch ice-age processes, by terrestrial feedback processes and/or by phenomena that we do not yet comprehend, they will occur. Some effects will be global, others regional and more local. They should be amenable to clear thinking and analysis, using traditional scientific methodologies instead of science as a weapon of fear.

The potential strengths and spirits of youth in our countries must not be dampened by continual images of gloom.

Concern for the environment must be balanced with concern for the total quality of life. No one should feel guilty because he has built something, and has pride in its excellence and an added spring to his step.

The motto unique countries like Canada and Australia must adopt is not simply the popular one of the Seventies:

Think globally, act locally.

That can shackle our futures unnecessarily. It is offensive to common sense to insist that these two countries, one unique in being the world's largest country and the other the most isolated and only island continent, should manage their environments to the lowest common denominator. The two countries are not the global average – they are unique and special.

Over the past decade or so, we have all become more aware and more sensitive to environmental needs and the efficient use of resources. Environment is considered routinely in developments together with the other E's of Economy, Engineering and Efficiency.

In such circumstances, where the population is environmentally literate but the greenhouse-bible-bashers remain very loud, we must also adopt a companion motto:

Think locally, and act globally.

The potential contributions that Australia and Canada can make to solve global problems will come from our activities, not our inactivities. They will come from our capacities to do things, and do them better and more efficiently, rather than from stopping development.

All that I can do, as a guest in your country, is to ask that you consider very carefully whether climate change has become a Holy War, and whether it is really climate change that is the reason for your interest in Greenhouse.

Let me close by saying I am not a total cynic but I was at the First United Nations conference in Stockholm in 1972 and I saw a lot of the United Nations bureaucracy start. That was a very heart-warming conference too, in 1972. Its major issues, apart from atmospheric nuclear testing and so on, was to 'Save the whales.' I'll end on a whimsical note. To the best of my recollection, that well-known whaling country, Sudan, was the nation that moved the resolution to ban whaling.

Thank you.

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Eve Savory: All right, we have a very short break now. Since we are running just a little bit behind and I'm going to be a disciplinarian, in 8 minutes from now the bell will ring to get you back in your seats and 10 minutes from now we will start again.

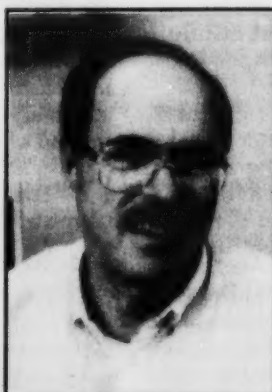
Ten minute break

Eve Savory: Hello again everybody. I'm glad you're all back. We will now have three short presentations under the general theme of an appropriate response, followed by questions. We will alternate between people at the microphone and the written questions that have come in; some are really provocative and thoughtful.

So our first speaker under the heading of appropriate response is Dr. Louis Hobson. He is Associate Professor and Chair of the Biology Department at the University of Victoria, and President of the Canadian Meteorological and Oceanographic Society. His research at the institute of Oceanography in Ocean Ecology and current scientific activities include the effects of environmental variables on aquatic plants.

Dr. Hobson is the author of many publications including phytoplankton biology in the waters of southern British Columbia. He is a member of several scientific research organizations, including the Canadian National Committee, Scientific Committee for an oceanic research under UNESCO.

Dr. Hobson.



Ultraviolet Radiation and Phytoplankton Photosynthesis: An Overview

I suppose in response I have very little except I would point out to our last speaker, Dr. Brian O'Brien, that the common confusion that's made between cause and effect and correlation is insufficient reason to stick our heads in the sand and quit worrying about what's going on in the environment.

That of course is meant to be a provocative statement. The last speaker also pointed out a very important facet of our knowledge that's lacking and that is where that extra

CO₂ that should be in the atmosphere, but isn't, has gone. Currently scientists are actively debating that question. Many believe that the extra carbon is in the terrestrial biomass of the northern hemisphere. Many others believe that it's in the ocean.

I think that regardless of where it is, I am particularly concerned about the impact of increasing ultraviolet light on that biomass, be it in the ocean or on land. My particular interest in this started in the early 1980s, when we carried out a study in the local waters of Saanich Inlet looking at the impact of ultraviolet radiation on phytoplankton photosynthesis. Phytoplankton are these single-celled microscopic organisms that form the fundamental basis of the food web in aquatic environments. We were unable to show any dramatic decline in the photosynthetic rates of these cells, even near to the sea surface we could show no large decreases. We did find that the maximum increase occurred during the spring and in the fall which suggested that different cells have different responses to ultraviolet radiation and that suggestion has now amply been shown to be correct.

There are differences among these cells such as their responses to ultraviolet light. Now recently, a period of 12 years have gone by and we've carried out a simulation study of ultraviolet effects on Saanich Inlet again based upon modern accurate measurements of the ultraviolet light flux into the water and the data generated and some very accurate measurements in laboratories. We were able to show that cells held near to the sea surface, artificially held there mind you, would cease to divide after a few minutes, whereas if the cells were held at five or six meters in depth, they were simply not affected. This is a clear indication of the rapid absorp-

tion of ultraviolet light by the top few inches of sea water. And we happen to be fortunate, as Gordon McBean has pointed out, in living in an environment that has a relatively thick ozone layer.

If we go to the Antarctic, many scientists are currently looking at the impact of ultraviolet light on photosynthesis in those waters, and they've now been able to show depressions in photosynthetic rates down to a depth of 25 meters. So, effects are observed considerably deeper in the ocean in high latitudes where there is an increased flux of light. So it may well have an important impact on food webs in the marine environment. Decrease the CO₂ uptake by the cells and change the kinds of cells that are there, and we simply can't predict at this point what that will do to the food web.

I'd like to end with a photomicrograph of an organism that is increasing in its notoriety, because they bloom over very large areas in the temperate latitudes of the Atlantic and Pacific Oceans. The organism in Figure 1 is called, in scientific jargon, *Coccolithophore*. That cell is very small, ten micrometers in diameter. A micrometer is a millionth of a meter so those are pictures taken with an electron microscope. The little scales are almost pure calcium carbonate. These organisms are magnificent concentrators of CO₂. They turn it into calcium carbonate. When the cells are eaten or die, those plates sink rather rapidly into the deep ocean. They take CO₂ out of the surface water and put it in the deep ocean where it is removed from contact with the atmosphere. So these organisms close to the sea surface are a very important sink for removing carbon dioxide from the atmosphere.

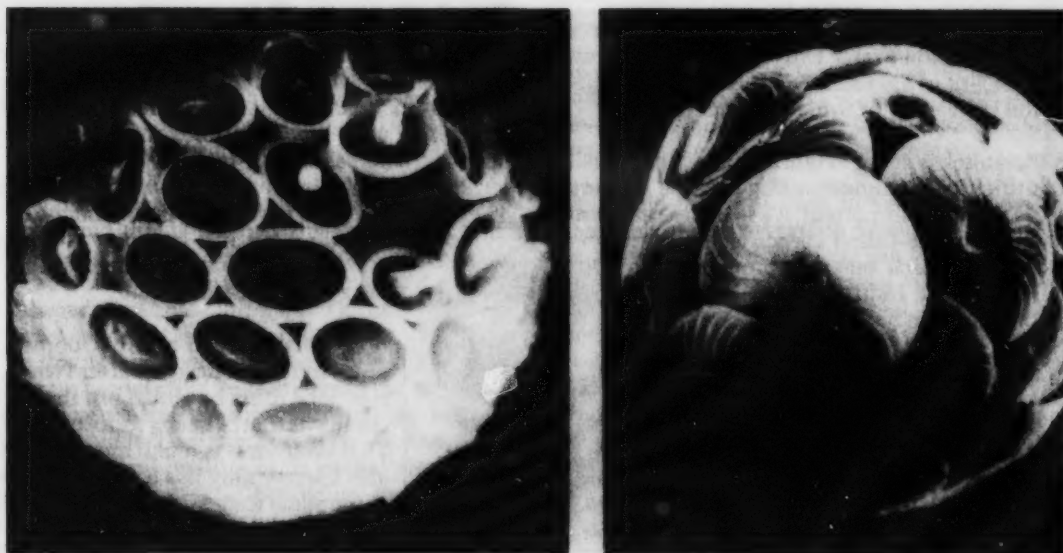


Figure 1: *Coccolithophore*, 10⁴ times Life-size

In addition, these cells do another very interesting thing. They make an organic sulphur compound. When they are eaten or die, this compound is oxidized to dimethyl sulphoxide, which is a compound that likes to be in the atmosphere more than in the water. Many scientists now believe that when those molecules rise up into the atmosphere, it's oxidized and the products of that oxidation are tiny particles, on which water will condense. Thus, these organisms actually contribute to the formation of clouds over large tracts of the ocean. So not only do they take CO₂ out of the surface layer of the ocean, they also are acting as a cloud-producing machine, if you will, which increases the reflection of irradians back into space and hence helps to cool the ocean surface. So they have the potential of being very very important, occur over wide areas of the ocean and are susceptible to enhance ultraviolet irradiation.

So I think that we definitely need to be concerned about what could be a positive feedback, increased UV leading to enhanced accumulation of CO₂ and I hope that Canada through our negotiators, through all of those politicians and all of those bureaucrats continue to lead us forward as a country that's very much concerned with these problems.

Thank you.

Eve Savory: Thank you. Our next speaker Dr. Michael Margolick is a Senior Resource Planning Coordinator with B.C. Hydro. In that role he incorporates electricity conservation programs into Hydro's electricity resource plan. As the principle of his own consulting firm, Dr. Margolick specialized in energy and resource economics and in energy demand analysis and forecasting. He has published numerous articles and papers on energy and resource economics. He is an Adjunct Professor in the School of Environmental and Resource Management at Simon Fraser University. He serves on the editorial board of the Journal of Business Administration at the University of British Columbia.

Dr. Margolick is going to talk about a subject that I have had difficulty in understanding because it's very complex but it's really important. It's what we call fiscal instruments, such as so-called 'carbon taxes' and the like, by which one can promote action on the part of industry or perhaps prompt it or force it in a desired direction.

Dr. Margolick.

My presentation concerns a research project that was conducted under the sponsorship of B.C. Hydro last year. It was done by arrangement with the Energy Council of Canada; the paper was submitted to and accepted by the 15th World Energy Congress which will take place in Madrid in September of this year. The work was done

by myself and another B.C. Hydro staff person, together with two people from the school of resource and environmental management at Simon Fraser and one independent consultant.

The objective of this report was to predict, in realistic terms, how Canadian heavy industries would respond to a greenhouse gas tax. Now, I think Doug Russell mentioned financial control instruments. A tax would be one of three possible control instruments.

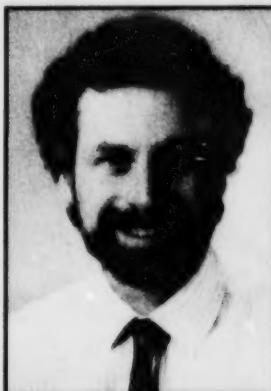
You could also have a regulated emissions cap. You could simply declare that by a certain date emissions have to be down to a certain level and leave it up to the industry how they would achieve it, or you could have a tax which is the second simplest instrument or you could have a system of tradeable emission credits such as are being implemented under the Clean Air Act in the United States for sulphur dioxide control.

The most popular of these instruments is a tax and at present there are a number of Nordic countries, there were four of them as of last year that have imposed carbon taxes, and carbon taxes are also under serious discussion in a number of other countries, including Japan and Australia. I think Doug Russell pointed out the need for international harmonization of policies on control of greenhouse gases and it's interesting that among the taxes under discussion or now implemented, the highest tax is about 75 times as high as the lowest tax and there are a wide number of other differences.

For example, some taxes are not strictly based on the carbon content of fuels while others are. Some taxes charge different rates for the same fuels used in different applications. Some of the taxes are intended to raise general revenue for the government and revenue from others is targeted to greenhouse gas reduction programs. But all these taxes have one thing in common. And that is that they all exempt energy-intensive heavy industry. The reason for that is that your automobiles and your homes and your shops are pretty much captive in your country, whereas energy-intensive industries tend to locate themselves in the countries with the lowest cost. They can locate their new plants pretty much anywhere, and they are run by large multi-national companies, so I think there is a bit of fear of job and investment loss.

This leads to my first point that we know the problem is global and we know the solutions must be global but the particular context is that of heavy industry as a whole. That awareness is much more important. In effect, everybody has to jump into the pool at the same time and to the same extent.

The second general point is that we seem to be coming to a sort of clash of basic economic models. The famous Canadian



economist, John Kenneth Galbraith, long ago did a study of American corporate investment behaviour, and any traditional economics book will tell you that for any business, the primary objective of investment is to maximize profits. What Galbraith was asserting a long time ago was that there seemed to be a greater drive towards expansion of production. Now, that's not to say that when expansions of production, the new plants, were built they weren't profitable. It's just that in many cases, there were more profitable alternative investments.

I think that we are possibly coming to an end of era, it's very hard to say, in which expansion is really viewed as the primary role of the firm and of course, one of the investments that is actually more profit maximizing than expansion, are plant modernizations and plant modernizations usually include lower energy use. So I think there's a bit of a clash, if you like. If you look at the conventional economic forecasts that are being produced by a lot of government agencies and industries themselves, you will see more or less a 'business as usual' forecast. Production will grow at 2, 3, 4 per cent a year and this kind of thing.

We know that there are international agreements coming forward to actually reduce or certainly limit the amount of greenhouse gases put into the atmosphere. And usually people say, "Well, the gap can be filled by energy conservation and efficiency measures," and it can be, but that gap can be very wide. The higher the production forecasts become and the stricter the greenhouse gas emissions are set, the wider that gap becomes. I think there's a prevailing sentiment out there that says, "Well, somehow, maybe we can have our cake and eat it too." We can have a high amount of production and we can have a super-efficient industrial sector just by throwing more money or more resources at energy conservation. While it is true that the theoretical potential for energy conservation can be significant, it is limited. Basically, if these agreements can be adhered to globally, I think in many cases they will be achieved through limitation and production of these goods.

I will move from the general to the specific. One reason for doing this is because the study dealt with specific things. It went on an industry by industry basis, even focused on specific industries and specific provinces in Canada but I also think there's another reason for doing this and that is that by becoming specific, we can bring things a little closer to reality. In fact, a lot of the economic models that have analyzed the impact of greenhouse gas control measures tend, in general, to be very abstract models. They simply don't take into account some of the practical realities of industrial production processes so the modelling procedure that we use, which is called an energy end use model, in effect simulates the investment decision that plant managers would make when faced with the different sets of fuel prices or greenhouse taxes and so on.

My point is that it's rooted in the engineering processes on which these plants are based. It's not an abstract model that uses some mathematical function to estimate things. To start with an industry that's close to home, the pulp and paper industry in B.C., one of the basic issues that would have to be resolved if a greenhouse gas tax were to be applied in British Columbia, is how much do you want to tax biomass?

To emphasize how important this is, let's look at smokestack emissions in the pulp and paper mills in B. C. Mills put out about 22 million tons of carbon dioxide a year. About 19 million tons come from biomass. There are two sources of biomass, one is the wood waste that we are all familiar with as an alternative energy form, but it's only responsible for 3 to 4 million tons. The rest is in the form of a substance called black liquor or, more generally, chemical recovery liquors. They are an intrinsic part of the kraft or sulphate process used to make most of B.C.'s pulp. The only way to get rid of black liquors is to burn them. They are a necessary by-product of the process and, in fact, they are burned in boilers to generate most of the steam used as the process heat for pulp reduction.

So point number one is that no matter what the level of tax is, as long as the same amount of pulp is being produced, these chemical recovery liquors will continue to be burned. As for the remaining wood waste, it's a very difficult question. You want to say, "Should we tax it or shouldn't we tax it?" Some people would say if the wood waste weren't burned in a boiler it would rot on the forest floor and you make carbon dioxide anyway so we shouldn't tax it. And other people say no, it should be taxed on the basis of smoke stack emissions. This is just one example from five or six industries studied. Every one of them has a different story to tell.

The cement industry could have a major reaction to a greenhouse gas tax because it can, to a degree, substitute other fuels. But energy is a large proportion of their production costs, so the cement industry could react quickly to a greenhouse gas tax.

The iron and steel industry, although by some accounts the biggest carbon dioxide producer in Canada, is basically constrained by the technologies used for making steel. I provide these as examples of things that can be more closely examined if we want to move towards a reality of greenhouse gas taxation.

Energy Efficiency and Fuel Substitution in Canadian Industry Under Greenhouse Gas Regulation

Michael Margolick, B.C. Hydro
John Nyboer, Simon Fraser University
Timo Makinen, B.C. Hydro
Sergio Gai, Independent Consultant
Mark Jaccard, Simon Fraser University

1. Introduction

As of June, 1991, Finland, The Netherlands, Sweden and Norway have imposed taxes on greenhouse gases, specifically carbon dioxide. Taxes are imminent in Denmark and Germany. Other countries including Japan, Australia, the United States and Canada, are analysing greenhouse gas taxation and other measures as a means to achieve the emission target of the 1988 Toronto Protocol on Climate Change. Canada's 'Green Plan' calls for stabilization of CO₂ emissions to 1990 levels by the year 2000. This objective will be restated at the 1992 United Nations Conference on Environment and Development, where international conventions on climate change are likely to be addressed.

The range of taxation levels both in effect and under discussion is enormous. Even among the countries with existing taxes, the highest tax is 75 times as great as the lowest. In addition, taxes are designed and applied differently. Some are not strictly based on the carbon content of fuels, while some are. Some tax schemes charge different rates for the same fuel in different applications. Some are intended to raise general revenue, while revenue from others is targeted toward policies to reduce global warming.

The more stringent tax policies exempt energy-intensive industries in order to keep them from relocating to countries without such taxes. It appears unlikely that any industrialized economy will impose a significant greenhouse gas tax on energy-intensive industry unless almost all other countries do so as well - and to a comparable degree. Otherwise the risks of plant closure and relocation will be considered unacceptable. The Toronto Protocol shows that the community of nations is willing to think globally about greenhouse warming. The industrial sector in particular requires a uniform global policy.

However, good policy must be preceded by good research. The industrial sector poses special problems for the analyst because assumptions which are true for only one plant, or at best all, plants of a certain vintage or technology type, must be generalized to the industry as a whole. On the other hand, there aren't enough plants to warrant the use of aggregate statistical techniques.

The most common approaches taken to date have been those of the economist and the process engineer. The economist's approach to analysing greenhouse gas taxation starts with a theoretical curve showing the effect on emissions of a tax. This is a single, smooth, continuous, downward-sloping graph as in Figure 1. The economist posits the existence of the curve and then attempts to measure its slope and position, traditionally through statistical means. By contrast, the engineer's approach starts with industrial process analysis, which is based in materials science, organic chemistry and physics, and works toward costing individual plant designs that are more energy efficient or less polluting.

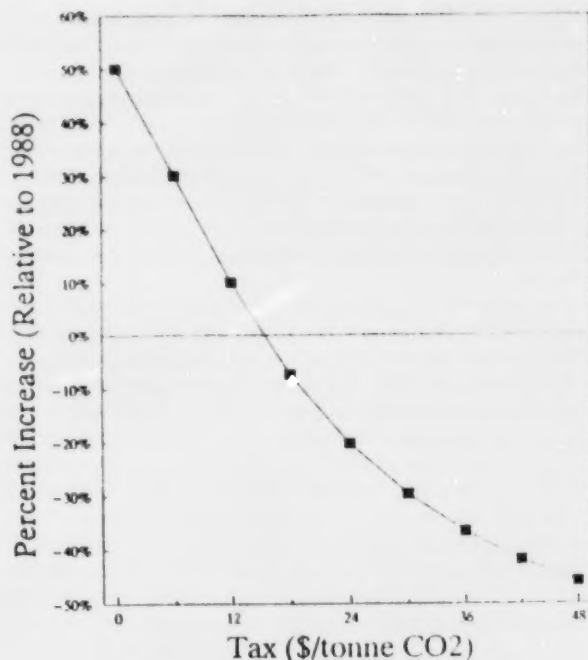


Figure 1: Response of Emissions to a Tax Levied in 2010

However, generalization to an industry and sector-wide policy analysis is not typically within the engineer's domain.

Our effort is oriented toward closing the gap between these approaches and creating new interactions between research communities. So far, our work in engineering-based economic analysis for specific industries in Canada has yielded some unforeseen results. In particular, the single smooth, continuous, downward-sloping graph of Figure 1 appears to be:

- Undefined or at least requiring far greater knowledge of forest science and future land management policy (in the case of pulp and paper),
- Highly dependent in slope and position on commercial availability of new technologies and on subsequent choices that would be largely independent of the existence of the tax (iron & steel),
- Flat, because either the least-expensive proven technology is the least emissive or because a potentially commercial technology exists that would be both greenhouse gas-free and less expensive than any proven one, even in the absence of a tax (aluminum smelting),
- Highly sensitive to minor changes in the relative prices of fuels which are now priced at close to parity (cement), and
- Determined primarily by changes in product chemistry, feedstock quality and overall demand for its products which would be induced by the tax itself, rather than by in-plant design changes (oil refining).

The broadest policy implication of the results is that the issues to be addressed in formulating actions or agreements on industrial greenhouse gas emissions must be industry-specific. Autonomous technology change may almost eliminate greenhouse gas emissions in some industries, even without a tax or regulation, while other industries would have to be very heavily taxed in order to achieve significant reductions without a corresponding drop in output. Some industries would respond quickly to a tax, substituting low greenhouse gas fuels for coal or heavy fuel oil at a moment's notice. For others, fuel-switching is heavily constrained by technology or chemistry. The only effect of the tax would be to raise the price of products in some industries, while causing major adjustment costs in others.

However, it would be economically inefficient to apply taxes selectively. Economic theory asserts that a uniform tax per unit of emission is more efficient than a mandated percentage reduction for each industry, and our work confirms it. The next step is to link models in an inter-industry framework in order to analyze a system of tradeable emission credits.

2. The Modelling Approach

The Intra-Sectoral Technology Use Model (ISTUM), an end-use energy demand computer model, was used to simulate firms' investment and fuel choice decisions and to embed the analysis into future scenarios of product demand, production structure and energy prices. ISTUM was originally developed for the U.S. Department of Energy, and has been the object of sustained effort in Canada since 1987.

In effect, ISTUM replicates the operation of a single plant whose outputs, inputs and process technology shares are the aggregate of the plants in the study area. If it were built for a single plant, it would represent a typical model regularly used in making capital decisions in the business world. However, flexibility in terms of modelling alternative assumptions for a whole study area makes it very useful as a policy analysis tool.

The ISTUM modelling approach starts with the development of an industrial process flow model which displays a tree structure with three basic elements:

- 1) Final product(s) of the industry. These are exogenously forecast.
- 2) Intermediate products. These are the material precursors of final products, as 'bleached pulp' is a precursor to 'writing papers.' The quantities of intermediate goods required are determined from final product volumes through fixed engineering coefficients. Allowances are made for shipments of intermediate goods outside of the study area, and the coefficients are verified against reported statistics.
- 3) Competition nodes contain the sets of technologies which compete in the manufacture of intermediate or final products. For example, in the

cement model, the wet process, dry process, dry process with preheater, and dry process with preheater and precalciner all compete in the production of clinker, a material precursor to Portland cement. Each technology may use up to six fuels (natural gas, oil, coal, petroleum coke, and perhaps waste-derived fuels and electricity). In the current version, 24 options are competed. Other nodes may have only one fuel associated with each technology: in the steel model, the COREX process can only use coal.

The model explicitly tracks vintages of equipment. As equipment ages and is replaced, as retrofit possibilities occur, and as new capacity is built to meet the product demand forecast, ISTUM will retire, retrofit and expand its equipment stocks on the basis of a technology choice algorithm. This algorithm determines the market shares of fuels and technologies within each competition node. Resulting fuel demands and greenhouse gas emissions are calculated from technical coefficients associated with the predicted mix of technologies and fuels in place in any given year.

The technology choice algorithm is based on life-cycle cost-minimization among technologies and fuels providing a specific industrial service, such as reduction of iron ore or cracking of crude oil. Life-cycle costs are based on average capital and operating costs, including labour, fuel and perhaps greenhouse gas taxes, and a specified discount rate. However, it is not automatically assumed that the investment of lowest average cost will capture 100% of the relevant market, as is the case with linear programming models. ISTUM has a technology share structure which allows for solutions that are not 'all-or-nothing.' The ISTUM algorithm will always assign a larger market share to a less expensive choice, but may be adjusted to increase or decrease the differences among market shares, based on a dispersion factor. The dispersion factor may be adjusted to duplicate historic investment shares, in effect calibrating the model for observed investment behaviour. In addition, exogenous maximum or minimum market shares may be imposed for reasons such as fuel availability, government regulation or product quality considerations.

3. Application of Greenhouse Gas Taxes

In our modelling, only CO₂ and methane have been considered. Greenhouse gas taxes are expressed in dollars per tonne of CO₂-equivalent, where the equivalent greenhouse effect of methane is assumed to be 8 times that of CO₂ on a mole-to-mole basis (21 times on a weight-to-weight basis). An underlying assumption is that all emissions are measured and taxed at the point of release. An alternative assumption would be taxation only of purchased fuels. The two assumptions differ only with respect to secondary fuels derived from untaxed feedstocks which are not commonly considered to be 'fuels', such as waste plastic. Our assumption results in taxation of all the CO₂ and methane molecules emit-

ted to the atmosphere by the plant or industry under consideration, and no others.

In particular, the volume of emissions reported does not include that due to fuels consumed in the production of purchased electricity. However, it is assumed that the tax is applied to electricity production and added to the price of electricity. The tax is based on weighted averages of the fuels used in generation, with allowances for transmission line losses. Similar purchased fuel price impacts result from the greenhouse gases released in coal mining and petroleum refining.

Tax impacts are obtained by running the model at the given tax and at no tax, and subtracting results. The impacts on energy consumption, fuel shares, greenhouse gas emissions and market shares of competing technologies in the final year of simulation, usually 2010, are reported. The costs of the tax are also estimated. These costs fall into two basic categories: the tax itself and adjustment costs. Adjustment costs consist of the change in the fuel bill, and the incremental capital, operation and maintenance costs of the new technology mix.

4. Limitations of ISTUM

ISTUM is limited by its partial-equilibrium aspect. In particular, it does not endogenously account for changes that would be induced by a policy, like a greenhouse gas tax, in either factor or output markets.

For example, an economy-wide greenhouse gas tax may increase demand for aluminum. However, in the aluminum model, the forecast of production would have to be exogenously adjusted for each separate tax in order to reflect this effect, and ISTUM could not be used to determine the appropriate adjustment.

Similarly, a greenhouse gas tax could induce price changes among competing fuels: natural gas demand would rise, while coal demand would fall. If these changes in demand were to affect economic reserve levels (supply curves were not perfectly elastic), then natural gas prices would rise and coal prices would fall. However, any fuel supply price effects due to the tax would have to be exogenously determined.

Finally, the impact of a greenhouse gas tax on the prices of material feedstocks such as ores, trees or chemicals, are provided exogenously.

The approach taken so far is to not change fuel or feedstock prices or product volumes as tax changes in the model, except for certain illustrative cases. This must be kept in mind when interpreting results. Embedding the analysis in a general equilibrium framework is a high priority and would combine the best features of both end-use and macroeconomic models.

Other aspects that are difficult to model include:

- Product quality. In our modelling, it is often nec-

essary to make a judgement as to when a bulk commodity is in fact a differentiated product. We have found that major investment decisions, even for energy-intensive processes, often hinge more on product quality than on energy costs. For example, different grades of pulp command different prices, based on the different strengths, opacities, etc. of the papers they produce. In the current pulp and paper ISTUM, separate competitions have been developed for chemical pulp and mechanical pulp. Whether these two types should compete, or whether there should be separate competitions for subgroups within these types is a matter of judgement.

- Non-energy feedstock quality. In parallel with the product quality issue, the particular characteristics of raw feedstocks impact on technology choice. For example, the available volumes and species of trees tend to play a larger role in the decision between chemical and mechanical pulping than does energy, and probably as large a role as product quality considerations. This further justifies separation into distinct nodes, although in theory a large enough greenhouse gas tax could swing an investment decision from one pulping technology type to the other.
- 'Housekeeping' conservation. Daily operation and maintenance practices may have a significant impact on energy consumption. These effects can be incorporated in ISTUM only by having 'low operating-cost' and 'high operating-cost' options associated with the same machinery. In effect, housekeeping may be included but not estimated.
- Like any end-use model, ISTUM may underestimate technical conservation potential, because in reality, each individual plant would be able to optimize separately, whereas ISTUM only optimizes the aggregate (average) plant. There are also more technology variations and possibilities than can be included in the model.
- Finally, in common with all economic models, ISTUM cannot account for unforeseen technology developments. A greenhouse gas tax could in itself cause new research, plant design and production methods which are not in the current option set simply because they do not yet exist. The magnitude of the effect is, by definition, not known, but past experience suggests that it could be quite significant. Many conservation technologies now commonplace would not exist if not for higher energy prices and environmental concerns.

5. Industry by Industry Results and Discussion

Industries were chosen on the basis of total energy consumption, energy intensity and data availability. Typical study areas were individual provinces with high industry concentrations. Wide variations in energy prices amongst the provinces forced selectivity on us.

5.1 Pulp and Paper (British Columbia)

Canada's pulp and paper capacity is located predominantly in the provinces of Ontario, Quebec, New Brunswick and British Columbia, with a small but growing amount in Alberta. Our model currently covers B.C. only, representing about 30% of Canadian pulp and 17% of Canadian paper capacity. Approximately 40% of B.C.'s pulp production is integrated forward into paper production, with the remainder sold on the international market. About 60% of current paper production in B.C. is newsprint.

The B.C. pulp industry is currently based mostly on the (sulphate) chemical process, which uses large amounts of process steam. New investment is primarily in the more fibre-efficient (thermo-mechanical) process, which uses steam generated by heat recovery and not combustion. Electricity is derived primarily from hydro-electric sources, which we have assumed to be free of greenhouse gas emissions. Mechanical mills require large amounts of electricity. Chemical mills self-generate significant amounts of their electricity needs.

Our product output forecast is based on a consultant's report and represents an industry consensus (Woodbridge Reed 1988). It shows a 24% increase in total pulp production and a 75% increase in paper production by 2010, with the difference due to increased forward integration of the pulp sector. Market share of mechanical pulp is expected to increase from 27% in 1988 to 46% in 2010 with a 20% drop in market share of chemical pulp.

Chemical pulp mill steam requirements are met largely through the burning of forest biomass. This includes lignin contained in chemical recovery liquors (CRL) from the chemical process and wood waste (bark produced on-site and sawdust/shavings/trimmings from local sawmills). The remainder of the steam is from natural gas and small amounts of heavy fuel oil.

At the outset of our research in this sector, a critical issue appeared: should atmospheric CO₂ contributions from the burning in pulp mill boilers of wood waste and CRLs be offset with 'CO₂ sequestering credits' for forest replanting? And if so, what is the net contribution to atmospheric CO₂ of the burning of forest biomass in pulp mill steam boilers?

Economic efficiency requires that every action which emits CO₂ should be taxed in proportion to CO₂ emitted as a result of that action, and every action which sequesters CO₂ should be appropriately credited. However, some have argued that forestry is practised sustainably, in which case net CO₂ emissions over the whole forest cycle are zero and no taxes or credits should be implemented.

The issue of sustainability of current or future forest management practices is beyond the scope of this

research. We have simply posited different degrees of biomass taxation, assuming that the tax rate for biomass fuels is some percentage of the corresponding tax for fossil fuels, per tonne of CO₂ emitted at the mill. The percentage would reflect the net greenhouse effect of burning biomass fuels, as a proportion of that caused only 'at the burner-tip.'

To illustrate the magnitude of the problem, note that two-thirds of 'burner-tip' CO₂ emissions in the B.C. pulp and paper industry come from CRLs and another 21% from wood waste. If the greenhouse effect of burning biomass fuels drops from 100% 'burner-tip' equivalence with fossil fuels to 0%, annual industry emissions drop from about 22 million tonnes to 3 million tonnes. Obviously, the impact of any greenhouse gas tax will depend critically on how biomass is taxed. Furthermore, the tax would affect almost exclusively the wood waste component of biomass fuels. This is because lignin/CRL production is directly proportional to chemical pulp production: organic material will continue to be burned to recover valuable pulping chemicals for re-use. No tax can affect CRL production or consumption without reducing chemical pulp output.

The current pulp and paper model has about 140 technologies clustered into 17 competition nodes. However, as with most of the other models, the principal effects of a greenhouse gas tax are localized in just a few of them. Since greenhouse gases are due principally to the raising of steam in this case, application of steam-conserving technologies and reduction of the carbon content of fuels in steam boilers are the only notable impacts of the tax.

However, in all cases where the tax significantly reduces emissions, the fuel substitution effects overwhelm steam conservation effects, due primarily to substitution of wood waste for natural gas, and to a lesser extent, oil. The degree of fuel substitution is critically a function of the degree of biomass taxation. When biomass is taxed at 50% of 'burner-tip' equivalence with natural gas, the prices of steam from either source are very close, resulting in little fuel substitution or greenhouse gas reduction. Indeed, based on the assumed product forecasts, biomass must be close to untaxed (corresponding to almost no net CO₂ emissions), before a 20% reduction below 1988 emission levels is possible. Even in this case, it requires a substantial tax or a high natural gas price to achieve the desired reduction. The importance of fuel substitution, compared to steam conservation, is illustrated by the result that when biomass is untaxed, total energy consumption increases with the tax. This is because wood waste boilers are less efficient than fossil fuel boilers.

Other effects of the tax are relatively minor, and include shifts to vapour recompression and computer control in steam-drying of paper, flash drying in lime

kilns, and a shift from chlorine/chlorine dioxide bleaching sequences to oxygen/chlorine dioxide sequences.

Figure 2 shows the response to a greenhouse gas tax, for some illustrative cases where biomass is untaxed. These are the steepest curves, because in any case where biomass is taxed, the opportunity for displacement of fossil fuels with wood waste is diminished. In Figure 2, natural gas prices and required rates of return (ROR) are varied. Case 1 shows the response for a low natural gas price projection (a price of about \$1.75 (US) per GJ, or \$73.50 per ton), consistent with today's price level. A 15% real ROR is assumed, for illustrative purposes.

In Case 2, the natural gas price has doubled, and Case 3 combines the high natural gas price with an assumed 8% real ROR, an estimate of the average rate of return on private capital invested in Canada. When natural gas prices are high, the tax has relatively little impact: most of the fuel substitution is accomplished by the natural gas price to start with. In Case 3, the use of a lower discount rate amplifies the price advantage of wood waste within life-cycle costs, which in turn induces most of the fuel substitution without a tax.

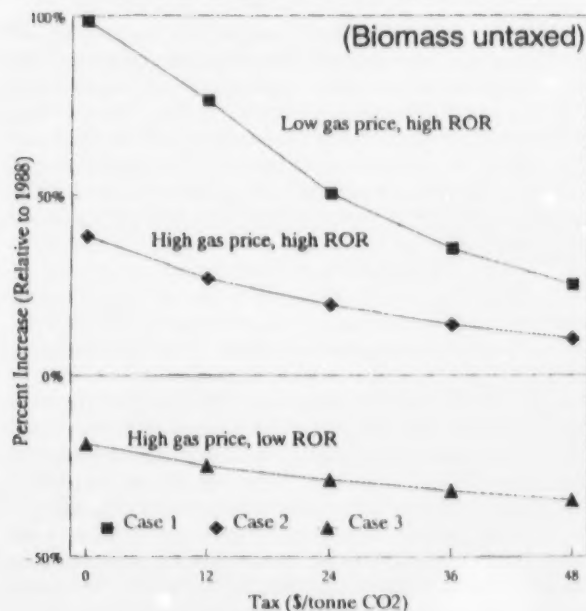


Figure 2: Response of B.C. Pulp and Paper Emissions to a Tax Levied in 2010

3.2 Iron and Steel (Ontario)

Approximately 12 million tonnes of steel product are produced annually in Canada, of which about 75% is from the province of Ontario. Integrated mills produce molten steel in blast furnaces and basic oxygen furnaces. Molten steel is then processed into semi-finished slabs, blooms and billets. Integrated mills comprise about

85% of production capacity, with the rest in electric mini-mills. Mini-mills melt 100% scrap steel, in electric arc furnaces, for subsequent casting.

Substantial modernization has taken place in integrated mills over the last four decades. For example, ingot casting has been fully replaced by continuous casting. However the basic technologies for molten steel production have not changed since the 1950s. The industry has experienced significant rationalization in recent years. Total capacity is unlikely to grow and may continue to shrink over the next two decades. Growth which does occur is likely to be in the mini-mill area, close to the sources of scrap metal.

Coal, in the form of coke as a reducing agent in blast furnaces, is the dominant fuel. Mini-mills use electricity almost exclusively. Ontario's power supply is nuclear (46%), hydro (27%), coal (24%) and oil/other (3%).

There are essentially two mutually exclusive investment paths for an integrated plant: the plant may continue with its current coke oven/blast furnace/oxygen furnace technologies through retrofits and modernization. Alternatively, it may move to direct reduction or direct smelting processes. These processes have the advantage of avoiding coke ovens, which are expensive, especially when (non-greenhouse-gas) pollutants must be controlled. Direct reduction processes make 'sponge' iron, which competes with scrap for processing in an electric arc furnace. Reducing agents may be supplied by coal or natural gas. Direct smelting technologies produce molten iron, similar to pig iron, for subsequent processing in a basic oxygen furnace. Coal-derived reducing agents are typically used.

The development of direct reduction and direct smelting technologies is a very active area. Some of these are mature technologies, like Midrex, a gas-based direct reduction technology now in use at one Canadian mill, while others are still pre-commercial. Possible direct reduction technologies include COREX and SL/RN. Possible direct smelting technologies include ELRED, SKF plasmamelt and Hismelt.

Although steel production is energy-intensive, energy costs are only about 6% of total production costs in Canada. Under these circumstances, how likely is it that a greenhouse gas tax could force changes in major investment decisions involving choice among technologies? A \$30/tonne greenhouse gas tax would approximately double today's price of metallurgical coal, raising total production costs by about 6%.

We examined technology shares under two alternative scenarios. Results must be considered only illustrative, as the set of 'eligible' direct smelting and reduction technologies appears to be changing rapidly. In the first scenario, blast furnaces are replaced 100% by direct smelting and reduction technologies, chosen from

Gardner (1989) and Lawton (1990). In the second scenario, the blast furnace option competes freely with:

- 1) blast furnaces with gas injection,
- 2) direct reduction, and
- 3) direct smelting technologies.

Energy, Mines and Resources Canada now considers these to be potential competitors (George, 1990; McInnis).

Technology shares for the two scenarios are shown in Figure 3. In the first scenario, greenhouse gas emissions in 2010, per tonne of steel product, lie more than 50% below their current levels, even with no tax. Although 85% of the capacity is coal-based, total coal requirements are significantly lower than today.

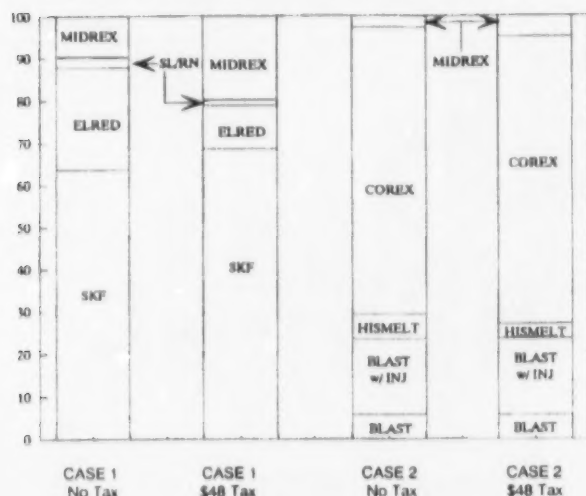


Figure 3: Ontario Iron and Steel Capacity Shares in 2010, by Technology.

A tax of \$48/tonne induces a shift to the gas-based Midrex process and coal-based SKF processes, at the expense of ELRED and SL/RN. While SKF uses coal, it is the least energy-intensive of the four processes examined. The tax induces an additional reduction in greenhouse gas emissions of only 8%.

In the second scenario, greenhouse gas emissions per tonne of steel product go down 30% in 2010 with no tax, relative to 1990. The dominant process is COREX, which is less coal-intensive than the blast furnace/oxygen furnace combination. While Hismelt (a coal-based direct smelting technology) makes some inroads, the gas-based Midrex process gains virtually no market share. Interestingly enough, the \$48 tax has little effect on either market shares or greenhouse gas production.

In summary, our modelling of iron and steel suggests that business strategies based on commercial availability of technologies and today's expectation of future

fuel costs are likely to set the basic direction for greenhouse emission levels in the Ontario steel industry, largely independent of greenhouse gas taxes. This is all the more true if the technology choices are made prior to the imposition of the tax.

5.3 Aluminum Smelting (Quebec, B.C.)

All aluminum production in Canada is located in Quebec and B.C. and uses solely hydro-electricity, which has been assumed to be free of greenhouse gases for this study. All plants use the Hall-Heroult process and any new developments would do so as well. In this case almost all of the greenhouse gases generated in the industry come from the manufacture of carbon anodes and their oxidation in electrolytic pot-cells. Consequently, a greenhouse gas tax on aluminum smelting in Canada would act primarily to reduce the rate of anode oxidation, or the amount of fuel used to form or bake anodes. The effect of a tax on this source of greenhouse gas appears to be minimal. Total Canadian emissions of atmospheric CO₂ from this source will amount to about 3.4 million tonnes in 1992. Oil or natural gas is used in the formation of anodes from petroleum pitch or petroleum coke, and, in most plants, to bake the anodes, which will result in further emissions of approximately 1.5 million tonnes of CO₂ in 1992. Based on current technologies and taking new plants and retirements into account, an 18% increase in annual CO₂ emissions, to 5.8 million tonnes, is expected in 2010.

The production of atmospheric CO₂ through carbon anode oxidation is governed by the chemistry of electrolysis. Oxygen electrolyzed from alumina will create both CO (carbon monoxide) and CO₂ at the anode. Further oxidation of CO will occur in the atmosphere. Anode consumption (or equivalently atmospheric carbon release) per tonne of aluminum is lowest when the CO₂/CO ratio in the pot-cell is maximized. This depends on anode composition and, to a lesser extent, on alumina bath temperature and other cell-specific factors.

There are three principal anode technologies used in Canadian plants: the Soderberg, pre-bake and Soderberg with Sumitomo retrofit. The older Soderberg process bakes anodes in the cell as alumina is electrolyzed. In more recent pre-bake plants, the anodes are baked, using natural gas or fuel oil, prior to use in the cell. Pre-bake plants use less electricity than do Soderberg plants, per tonne of aluminum, but require additional heat (oil or gas) energy to pre-bake the anodes. Soderberg anodes produce slightly more CO in the cell than do pre-bake ones, resulting in about 14% more greenhouse gas emissions per tonne of aluminum. The Soderberg/Sumitomo technology produces slightly less atmospheric CO₂ than the standard Soderberg technology, but more than the pre-bake, per tonne of aluminum. Conversion to pre-baked anodes in an existing plant would be prohibitively expensive at any plausible rate of CO₂ tax. Alterations in cell temperature or chemistry may be available, but these would have relatively minor effects.

Given the apparent immutability of anode technologies in existing plants, is there potential for a greenhouse tax to affect emissions in new plants? New plants are expected to use the pre-bake technology, which is the least expensive per tonne of aluminum even at no tax. Consequently, the tax-response curve must be close to flat. The tax effect would be to raise the price of aluminum, with minimal impact on emissions.

The above discussion is based on the assumption that only currently proven technologies are available. However, there is one major pre-commercial technology that would eliminate CO₂ emissions from anode oxidation. Stable anodes are ceramic/metal (cermet) electrical conductors which deteriorate very slowly and contain no carbon. When they are used in conjunction with stable cathodes made of titanium diboride, electricity consumption per tonne of aluminum is lower than with current methods. Energy needed for the manufacture of stable anodes would be far less than for carbon anodes, since they last about 130 times longer for the same rate of aluminum production. This would lead to near-elimination of CO₂ release in the anode manufacture stage as well (Galambas et al., 1988 and Pritchett et al., 1987). Existing plants, both pre-bake and Soderberg, could be retrofitted. Preliminary cost estimates show that retrofits would be highly economic even in the absence of a greenhouse gas tax. Consequently, if stable anodes are available, the response to a greenhouse gas tax by the aluminum smelting industry would still be essentially flat, at a level close to zero instead of the 5.8 million tonnes/year range for 2010 suggested above.

5.4 Cement (Quebec, Ontario, British Columbia)

Cement manufacture is the single most energy-intensive industry examined. Approximately 79% of Canadian capacity is located in Quebec, Ontario and B.C. CO₂ emissions in the three provinces add up to about 5.5 million tonnes per year. Roughly one third of today's CO₂ emissions arise from the calcining process, rather than from fuel combustion. Emissions per tonne of cement from calcining are inevitably fixed.

Approximately 40% of production costs in Canada are for energy, principally in the form of high-temperature heat. Most cement plants have multi-fuel capability. Thus, if ever there were an industry in which a greenhouse gas tax would have a major impact, one would expect it to be the cement industry.

Two dimensions of choice in response to a tax exist for cement plants: technology and fuel. It is possible to burn up to six fuels, either separately or combined, in each of four different cement technologies. Greenhouse gas impacts due to a tax appear to be a balanced combination of these effects. For example, results suggest that about two-thirds of the greenhouse gas reduction due to a \$48/tonne tax would be due to fuel substitution effects and one-third to energy conservation, resulting from shifts among production methods.

Figure 4 shows total energy and greenhouse emissions for the three provinces combined, together with emissions and energy per tonne of cement. Figures 5 and 6 show fuel and technology shares corresponding to energy consumption and emissions in Figure 4, respectively. Production is assumed to increase at 2.0% per year over the 20-year time-period. In the no-tax case, low coal prices tend to sustain a recent shift towards that fuel, causing emissions per tonne of cement to rise to 11.5% above 1990 levels. A \$48/tonne tax induces a drop in emissions per tonne to 17% below 1990 levels. However, total emissions increase because production has increased by 48%.

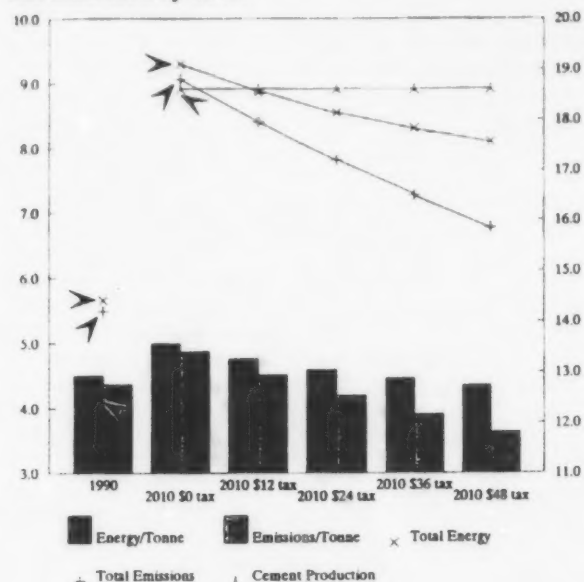


Figure 4: B.C., Ontario and Quebec Cement Plants: Unit Emissions, Unit Energy and Total Energy

We have observed that the costs of competing fuels have historically been close to parity. This is perhaps because of industry's flexibility in fuel choice. Whether or not this would also be the case after greenhouse gas taxation depends on both supply elasticity of fuels and demand-side market structure. If, for example, supply costs of fuels are not changed by the tax (infinite supply elasticity), then a small tax could initially flip the fuel market from high-greenhouse to low-greenhouse fuels. After a period of adjustment, though, high-greenhouse fuels may be able to regain some market share. Effects such as these make the slope of the tax-response curve very sensitive to changes in assumptions about future fuel supply costs to the industry.

5.5 Oil Refining (Ontario, Alberta)

Ontario and Alberta have 27% and 21% of the oil refining capacity in Canada, respectively, and emitted about 3.9 and 3.4 million tonnes of CO₂, respectively, in 1990. Canadian refineries are, in general, small by world

standards, having been established to serve regional markets. Some refineries are 50 years old, but all have been upgraded over time. Generally speaking, Canadian refineries are modern, but not state-of-the-art.

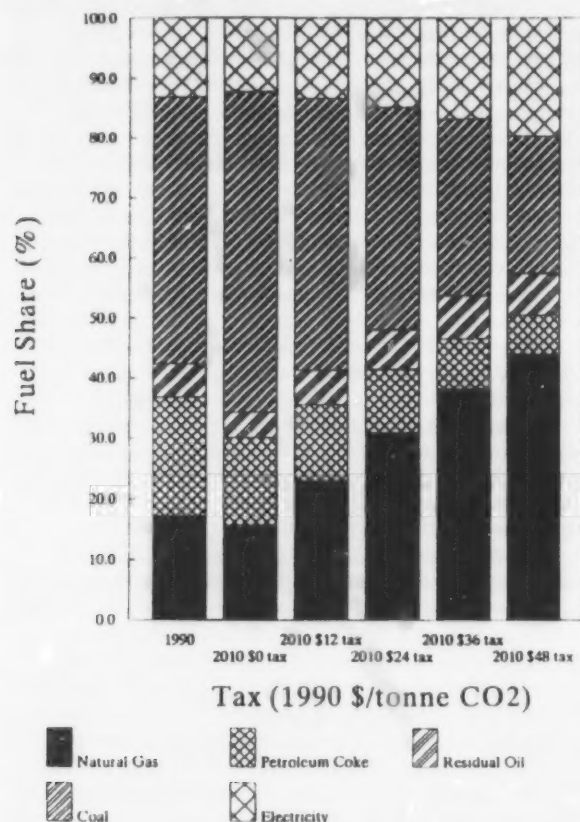


Figure 5: B.C., Ontario and Quebec Cement Plant Fuel Shares in 1990 and 2010

Our modelling excludes tar sands operations in Alberta, which produce syncrude from bitumen. Tar sands plants are a major source of greenhouse gas.

Oil refining consists of a sequence of complex chemical and physical re-arrangements of hydrocarbon molecules. Since refining involves both the processing and consumption of carbon-based fuels, the model is more complicated than any of the others. In addition, the process steps and degree of refining required depend critically on the quality of crude oil input and required product yield.

Over time, we expect that the quality of crude oils available to Canadian refiners will decline in terms of both density (API gravity) and sulphur content. For illustrative purposes, we assumed very poor quality crude oils for 2010 (2.5% sulphur, by weight, and 25° API gravity). Declining crude oil quality would lead to more cracking and hydrotreating, each of which would

increase refinery energy use. Gasoline is the largest product by volume, typically 40% of total production, and the most refined. There is increasing pressure on the industry to reformulate gasoline to reduce air pollution, such as sulphur dioxide emissions. Reformulated gasoline contains fewer aromatic compounds, less sulphur and more oxygenates than today's gasolines. Reformulation would, in itself, increase energy consumption and therefore greenhouse gas emissions in refineries.

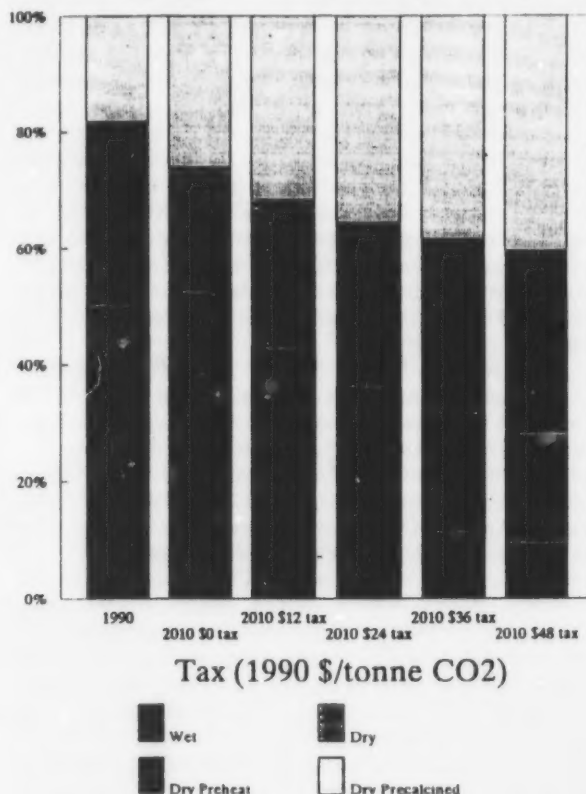


Figure 6: B.C., Ontario and Quebec Cement Technology Shares in 1990 and 2010

The oxygenates in reformulated gasoline are blended with finished gasoline just prior to shipment. Oxygenates are expected to be produced by the petrochemical industry, mostly from natural gas, although they may also be produced from petroleum or biomass. Greenhouse gas emissions from oxygenate production have not yet been included in our totals.

Neither the changing product composition requirements nor feedstock quality are greenhouse-gas-related. However, we have modelled the effects of greenhouse gas emissions of these trends separately, and in conjunction with a greenhouse gas tax.

In each of Alberta and Ontario, CO₂ emissions per tonne of refined product would be about 20% higher in

2010, given expected crude oil quality and reformulated gasoline requirements, than it would be without them. In Alberta, the requirement for low-sulphur products combined with the use of high-sulphur crudes necessitates a 53% increase in the amount of hydrotreating to remove sulphur, a 12% increase in direct heat requirements, and a 19% decrease in steam production. The reduction in steam derives from the fact that steam would be generated in new sulphur recovery plants.

Any greenhouse gas tax would have to offset the over 20% increase in emissions per tonne of refined product on top of improving process efficiencies or substituting fuels. However, it does not appear that a great deal of in-plant emission reduction would be induced by the tax. Opportunities for fuel substitution, beyond those which would have occurred without the tax, are relatively limited because, aside from purchasing additional natural gas for energy purposes, the refinery is constrained by the carbon-to-hydrogen ratios of the petroleum fractions available as possible in-plant fuels and by minimum acceptable product specifications.

When natural gas is purchased, the oil fractions that would have otherwise been burned would instead be further processed, resulting in more emissions. In addition, in Alberta, the natural gas share of purchased fuel is close to its maximum feasible level even without the tax. As well, Ontario refineries currently have limited gas access because of pipeline constraints.

Modelled results show CO₂ emission reductions on the order of 5% in response to even a \$48/tonne tax. Limited conservation is apparently induced by the greenhouse gas tax because industry investment criteria appear to cause most of the technical conservation potential to be realized over the next 20 years anyway. The effect is one of efficient new equipment replacing old, inefficient equipment as the economic life of the latter ends. For example, under a scenario assuming heavily declining crude oil quality and reformulated gasoline requirements, hypothetical Ontario refineries containing today's mix of technologies in service would use about 62% more energy per tonne of product in 2010 than today. This would be reduced to 41% through investments earning a 15% real rate of return or more.

Finally, a greenhouse gas tax on the burning of oil products will clearly have a major effect on demand. Given that normal refining energy losses are less than 10%, the potential for in-plant greenhouse gas reduction is far less than the probable effect of a greenhouse tax on oil product consumption. By way of illustration, if gasoline prices increase 1% faster than inflation each year over the next 20 years, a \$48/tonne tax would induce a 16% increase in the gasoline price. If price elasticity of demand is -0.7 (Berndt 1989), then gasoline demand would drop by about 11%, with a corresponding drop in total refinery emissions. This may be com-

pared to a 5% tax-induced reduction in emissions due to in-plant process changes.

6.0 Conclusions

Different basic physical and chemical processes among industries would cause widely varying responses to a greenhouse gas tax. These differences tend to be masked by an aggregate approach, but are revealed by technology-based end-use models. This exercise for Canada examined specific energy-intensive industries and found different issues which bear directly on greenhouse gas emissions, in particular response to a greenhouse gas tax. Issues include taxation of the burning of biomass fuels in the pulp and paper industry, strategic choices between existing and new technologies in the iron and steel sector, the possibility of a nearly greenhouse-gas-free aluminum smelting sector, and the advent of reformulated gasoline requirements and declining crude oil quality in the oil refining sector.

This research focused primarily on greenhouse gas taxation. However it is also a first step to analysis of inter-industry allocation of tradeable emission permits.

Notes

1. Taxation is one of the three principal ways to control emissions. In addition, a specific emissions cap may be required on a per-industry or per-unit-of-product basis, or a system of tradeable pollution permits may be implemented. Taxation was chosen here because it appears to be the most common form of control and was capable of being modelled quickly. However, there are linkages to the other two forms of regulation.

In theory, fuel and technology allocations and costs associated with a regulated emissions cap are equal to those caused by a tax just high enough to induce the required reduction. Therefore, the cost-minimizing response to an emissions cap may be estimated, together with the corresponding adjustment costs. However, our research suggests that in the industries examined, either:

- the cap would be achieved at no tax, because of autonomous technological change or a predicted reduction in industry output, or
- no 'reasonable' tax would induce the required reduction without a drop in forecasted output, for one or more of these reasons: the absence of low-greenhouse technologies, the small share of fuel costs in total production costs (despite the industry's designation as 'energy-intensive') and simply because of the chemistry of production.

If our industry-specific modelling is incorporated into a general equilibrium (inter-industry) framework, we will be able to model the effect of a system of tradeable credits. Even before that time, however, the relative responses of different industries to a tax will give an indication of how different sectors would be trading their initial endowment of permits: industries

with flat tax-response curves would be buying and those with steep curves would be selling.

2. See Cutter Information Inc., 1991.

3. The model was adapted for the personal computer by Mark Jaccard of Simon Fraser University and Joe Roop of Battelle Pacific Northwest Laboratories. See Jaccard and Roop, 1990.

4. We have generally used a 15% real discount rate. However, a number of empirical studies (Sassone and Martucci, 1984) show that industry managers tend to require extraordinarily high rates of return for investments whose main purpose is to conserve energy, in contrast to plant expansion or replacement.

5. This may be contrasted with standard optimization models, whose solutions are mathematically forced to allocate all new investment to the single choice of least average cost, unless carefully constrained.

Aside from behavioural aspects, which are no doubt very important, there is a straightforward economic reason why the technology or fuel of lowest cost (as averaged among all plants) should not get 100% of new investment. In the real world, the technology or fuel which may be cost-minimizing in one plant may not be cost-minimizing in another. Consequently, even if each firm chooses investments solely on the basis of minimizing production costs, there will still be plants choosing technologies or fuels whose average cost is higher than the average cost of some other technology or fuel. The ISTUM solution is an *ad hoc* attempt to resolve this basic aggregation problem.

6. The greenhouse effect of methane emissions depends on the time interval under consideration and on atmospheric chemical reactions which are only partially understood, as well as on instantaneous radiation absorption. Methane is a far more potent greenhouse gas than CO_2 , in terms of instantaneous radiation absorption – estimates range from 16 to 32 times, on a mole-to-mole basis. However, its average atmospheric lifetime is much shorter. On the other hand, methane oxidation produces CO_2 and other greenhouse gases through a complex series of atmospheric chemical reactions. In order to measure the relative impacts of methane and CO_2 release, the greenhouse impact of methane is expressed in terms of CO_2 -equivalency on a time-averaged basis over 100 years, from Coombs (1990).

7. Although there is some evidence on methane emissions from flooded peat lands, we have assumed that hydro-electricity is 'greenhouse-gas-free.' The effects of the tax on electricity prices range from zero to substantial, depending on the province under consideration. For example, Quebec's electricity is almost exclusively hydraulic, where Alberta's is 90% coal-based. In all cases oil and natural gas production and

refineries emit only a small fraction of the greenhouse gases released through the combustion of their products. Canadian coal mines are generally surface mines which tend to contain less trapped methane than underground mines. However, coal used in electricity production in Ontario is mostly from underground U.S. mines where significant methane venting occurs.

8. In fact, two major mills have re-bricked and remodelled their blast furnaces, for expected life extensions of 15-25 years. As well, direct injection of oil and natural gas into blast furnaces is now in effect. This reduces, but does not eliminate coal consumption.

9. For a description of these technologies, see George, 1990.

10. Although COREX uses more coal per tonne of pig iron than a blast furnace uses coke, it takes 1.4 tonnes of coal to make a tonne of coke.

11. Atmospheric CO release is assumed to have the same greenhouse effect as CO_2 release, on a mole-to-mole basis, since atmospheric CO will oxidize to CO_2 in a few months.

12. Sumitomo retrofit will in general reduce electricity intensity and control PAH (poly-aromatic hydrocarbon) emissions in a Soderberg plant.

13. Based on data in Exhibits 15, 18 and 19 of Galambas et al. (1988), adjusted for lower Canadian electricity prices, real rates of return of 37 and 55% were estimated for prebake and Soderberg retrofits to stable anode technology, respectively. The rate of return was determined as the real discount rate which made the present value of the total costs of the stable technology equal to the present value of the saved variable costs of conventional technology.

14. We also examined scenarios in which hazardous and refuse-derived fuels were allowed to compete. However, the same problem in measuring greenhouse impact occurs as in the pulp sector: what is the contribution to greenhouse warming of these alternative fuels? If the greenhouse impact of hazardous or refuse-derived fuels is small, then all plants would switch to them anyway, because the direct fuel cost is small or even negative.

15. While it is expected that light, low-sulphur crudes will be available on the world market for some time, Canadian policy leans towards the upgrading of Canada's heavy oil and tar sands reserves. In general, the greater greenhouse gas emissions associated with refining of heavier, high-sulphur crudes would cause increased demand for lighter low-sulphur (offshore) crudes and widen the price gap between crude types under a tax. Current projections are that Ontario will continue to use Alberta crudes but will also require offshore oil. Alberta

refineries are located well inland, adjacent to heavy oil deposits. They would tend to use increasingly heavy local crudes under any plausible circumstances. The upstream effects on quality-based crude oil price and supply differentials lies in the category of general equilibrium effects that have not been addressed here.

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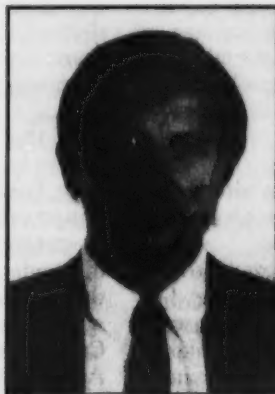
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Eve Savory: I'll tell you one thing I'm learning and that is that none of this is going to be easy.

Our last speaker this evening is Dr. Douglas Ross, a professor of political science at Simon Fraser University. Dr. Ross' recent work has examined the prospects for security cooperation in the Pacific Basin, naval arms control, the Canadian-American defense relationship and the U.S.-Soviet strategic rivalry. He has served on the consultative group of the Canadian Ambassador for Disarmament and on the Arms Control Centre Board and Council of Advisors. He's the author of many books and articles on arms control, maritime strategy and political issues in the Pacific region. Lately his interests have moved towards conflict studies, of the kinds that might arise during a period of environmental degradation and the collapse of nations.

When I was in New York last week, I met some people from the Alliance of Small Island States, which is a group of 37 islands, some of which are less than a meter above sea level, and all of which are terrified at the prospect of a rise in sea level. And the Ambassador from Papua, New Guinea said to me, "You realize that you can retreat from Prince Edward Island. You can go inland. We have nowhere to go, so if we show up on your doorstep you are going to have to take us in!" With that to think about, here's Douglas Ross.



The Political and Strategic Context for Global Climate Change

Thank you, Madam Chairman. That was, in fact, a very appropriate introduction. Let me explain briefly what seems to me to be the reasons why so many governments are leaping on board this particular Global Warming Convention, this atmospheric treaty.

I think, indirectly, that a lot of it has to do with growing fears of environmental and economic deterioration in much of the third

world. It is not coincidence that this Conference is not just about the atmosphere. It's about environment and development. It's a continuation of the Brundtland Commission effort, and it's a continuation of Willy Brandt's earlier work in the early 80s and so forth.

Now, this is essentially I think, a product of more than anything else, fear, and to that extent I'd agree with Dr. O'Brien that indeed there is a lot of anti-growth sentiment out there. There is a lot of irrationality. More charitably one would simply say it's intuition. I think there's a nagging fear, not just among white wealthy liberals in the global north, that the world is in trouble. In a way, this treaty is an area where we can perhaps achieve a 'lowest common denominator' in terms of getting a statement of principles and setting up targets.

This whole process seems to be very similar to what we have gone through on the question of nuclear armaments, where 45 years ago we had an initial stab at trying to create a nuclear arms control regime, a disarmament regime which failed. We then got into a long arms-race. It was extremely difficult, but the turning point, in a way, came in 1968 with the establishment of the Non-Proliferation treaty. That treaty, I think, will probably show a number of parallels when juxtaposed to this particular document which is just going to be blessed, I guess, in Rio.

The Non-proliferation Treaty is essentially a series of assurances and commitments which are made tangible and concrete and are then open to verification. It's a regime for creating confidence, reciprocally and that, I think, is what we are going to see coming out of this kind of atmospheric treaty negotiation.

In particular, where does the fear stem from? I think it's not just a sense that industrial society or industrial civilization is out of control. Governments are worried for very tangible reasons. Very briefly, I would note that in the last two and a half years we've had a number of very specific warnings by major leaders. In 1990, President Gorbachev warned the western European community and specifically his German diplomatic allies and contacts, that if the Soviet Union were to disintegrate economically and politically, if it did not receive the assistance which he knew it was going to require, there would be, in his words, quote "...a flood of refugees and armed conflict."

Russia and the other successor states desperately need assistance. He pointed to the fact that agricultural production was undoubtedly going to drop, that there were massive difficulties throughout what was left of the Soviet State apparatus and that recovery was not going to be quick and easy. Some German analysts looked at this problem and forecast unemployment rates in the successor Soviet States running to 50 to 100 million people within five years. Now, those estimates are not terribly wide of the mark but what it suggested to,

among others, the German Government, is that there is a very real risk of not just 300 refugees a month moving westward, but a torrent of people, not just coming out of eastern Europe but also coming out of Russia itself. This is a vast country, with a very large population in very desperate circumstances.

The second threat, very similar, was made by Premier Deng Xiao Peng, again in 1990, who spoke in a series of pointed press interviews. He doesn't give many press interviews about the risk of disorder in China; but once, he did. He said that if the state apparatus were to collapse and if the Chinese Communist Party were to fall apart and China was to fragment, he suggested that in fact the risk of massive population migration was very serious, that indeed tens of millions of Chinese might pour across the border into southeast Asia. And this immediately struck a nerve or an anxiety which has long been active in the Japanese body politics. They have what you might call a boat people reflex. They are desperately worried about something like the Vietnamese boat people coming north, only their fear is not Vietnam, their fear is a China in disintegration.

The third threat I want to mention just before talking a bit about what the options for Canada are, and some of the difficulties we face, in particular difficulties to the south, is the threat which President Carlos Salinas de Gortari of Mexico articulated in his state visit to Canada one to two years ago. His comments, in fact, have been subsequently reiterated by the Mexican Ambassador to Canada and by other eminent senior officials who come here selling the North American Free Trade Agreement. This argument has been made repeatedly in speeches across the United States as well. They say, "If Mexico does not get an acceptable and early free trade agreement which leads to a rapid increase in prosperity in Mexico, you are going to see a lot more of us because we are coming north. Millions of our citizens will be leaving and we can't stop them." Now, that is not a vague and idle threat either.

I submit that this is, among other reasons, why suddenly all the G7 countries, all the leading authorities in the western world, the northern world, are now taking the problems of environmental deterioration and what they see as the imminent ecological/economic collapse of many societies very seriously indeed.

Africa is the most visibly tortured continent on the planet but quite clearly, not because of just problems of global warming or ozone depletion, the existing menu of stresses which have already been exhaustively itemized and described in the Brundtland Commission Report and undoubtedly will be gone over again and updated in the Rio proceedings, give us cause to say that the world is entering a dramatically different era.

Here, I think, a couple of quotes are in order. Michael Shenstone, who was a senior civil servant in the

Department of External Affairs for almost 40 years, retired recently. I suspect he was probably involved in a fairly important report which gained wide circulation within the Canadian government and was leaked to the Canadian press last June. The gist of this report, an official Canadian intelligence estimate drafted by the Federal Intelligence Advisory Committee said, "Canada can expect to have increasing numbers of environmental refugees requesting immigration to Canada, while regional movements of the population at home, such as from idle fishing areas, will add further to population stresses within the country. We believe that a significant environmentally-related disaster or conflict may occur before effective international agreements can be worked out. One possible scenario relates to a changing world climate serving to set off a series of environmental catastrophes."

This was leaked to the Canadian press. Paul Mooney wrote it up in very brief and elliptic terms, unfortunately. It would be nice to see the full text released. Apparently most of the material which it drew upon was publicly available. What is interesting is their forecast of major difficulties in Asia, south Asia and east Asia in particular. China and India are very much at risk and again the risk is population movements, the like of which we have never seen in recorded history. It would make the movements to North America from Europe look very small by comparison.

This sobering reality is the backdrop to all of this energy being devoted to building what I hope will be the foundation for a new international consensus and creation of a new global management order; a new global system of governance. I think, being a Canadian, I would rather use the term 'an emerging world community', not an 'emerging world order.' Essentially, a treaty like this must be fundamentally based on consensus; and a growing area of consensus is essential. Any other way, which is suggestive of coercion, would open the door to disaster. That is something we have to avoid.

I think from what I hear from Doug Russell, we've made a very important and very positive series of steps in concluding this treaty. But all of the other problems are still there.

Frankly to me it does matter to some extent whether we have good science at the bottom of Dr. O'Brien's pyramid, and that our store of knowledge, of good science, is growing. Undoubtedly there are all sorts of assumptions which have to be built upon that, and scenarios which go beyond that and you will have this large pyramid. It reminds me very much of nuclear strategy, and the debate about whether nuclear wars were winnable or not. We called the top end of that 'nuclear theology.' And indeed there were warring camps and debates which went on for decades. Well, finally in a way I think the global community woke up, it realised that the lowest common denominator proved

that there was a sense that nuclear weapons were somehow profoundly inhuman. They were dangerous to the existence of human life on earth and that is why I think we are seeing this rapidly increasing progress towards de-nuclearization.

In the same way the international community generally is becoming more and more literate and self-aware, despite the deadening effect of a lot of TV programming. We have entered a new era. We have entered an era of global communications where I think the intelligentsia of all governments all over the world have made possible revolutionary political steps at co-ordination and co-operation.

On that positive note, I will reject the label of being an eco-doomster and a nuclear strategy doomster. Frankly, I'm really buoyed up. I think we've seen such enormous progress in the last five years, we have no where to go but up.

Thank you.

Eve Savory: Doug, I'm so glad that we can end on a cheerful note. All right, we are now going to answer questions. I would just like to quickly summarize some of the main points to remind you what we have learned.

From Dr. Gordon McBean: while there is agreement on the reality of ozone depletion, there's still a great deal of uncertainty about the long-term effects of carbon dioxide emissions and global warming. Nevertheless, he feels that there is some urgency for action and he doubts that since we will probably be unlikely to see a real reduction in the gases, he feels we must also start learning how to adapt and to improve our modelling.

From Mr. Douglas Russell: there is action coming on the international level. A question some of you may want to ask is: Is it enough? In fact some of the questions I have before me will deal with that very question.

From Dr. Brian O'Brien: we've learned that the science does not have the answers yet and we have to be wary of leaping into unwarranted international programs which he terms the 'Greenhouse Holy War.'

From Dr. Louis Hobson: important information about the adverse effects of increased ultraviolet radiation upon marine phytoplankton; and about a fascinating organism, the coccolithophore, which, if it declines due to increased ultraviolet light, we would get a positive feedback and more CO₂. Have I got that right?

From Dr. Michael Margolick: who is very sceptical that we can bridge the gap between industry's 'business as usual' expansionist attitude and the belief that we can reduce our carbon dioxide emissions by energy conservation. An interesting viewpoint from someone who is in the Resource Planning Department at B.C. Hydro.

And finally, from Dr. Douglas Ross: there is irrationality in the arguments for global warming but there's also an intuitive sense of danger, and that perhaps this threat of economic and environmental refugees may be why the G7 countries are acting.

So I thank you all. I found this to be a really stimulating session.

Now, I have a whole lot of questions here, most of which are difficult to read. So we'll start at the microphones, while I sort through these questions. Microphone on my left, please.

Adrienne Peacock: I'm Adrienne Peacock. I have a very general question. I would first like to comment that while I find Dr. O'Brien's critique interesting, I think that, if you went through the scientific literature, you could probably find just as many examples where correlations were ignored as cause and effect which later turned out to indeed be cause and effect after all, and caused years of suffering.

We only have to look at cigarettes and lung cancer as one example; and the asbestos industry, where the asbestos companies denied any correlation with lung problems for years and years, and as far as I understand are still claiming they are unconvinced; to find out how important it is to look at correlations and take the signals appropriately.

So my question then is, because I think we have to assume that there's something real here. I think we have to assume that we have a problem and I would like to ask everyone but Dr. O'Brien because I think that he is probably like Japan and the whaling industry. Australia, after all does export a lot of coal. I would like to ask everyone what you would recommend. I know there are problems but if you are assuming that there is, indeed, a strong possibility of global warming, then what would you recommend we do right now?

Gordon McBean: Well, I think there are things that we can do immediately to reduce our emissions of greenhouse gases. I think we should be looking first of all at those things that make sense for a variety of reasons in addition to the greenhouse question.

Those of us who live in Vancouver and don't have the benefit of living in Victoria know that we have something called urban air pollution that's created due by fossil fuel consumption, primarily from automobiles. We should be worrying and trying to reduce our use of cars by promoting buses and skytrains and even electric vehicles to reduce our exhaust emissions.

So I think there are things we can and should be doing about reducing our emissions, such as supporting the reduction of CO₂ values by the year 2000 to the emission levels of 1990, which is what I believe the

Canadian Government is committed to. Actually reducing CO₂ by 20 per cent or 40 per cent would be very much more difficult and expensive. But I think we should be certainly moving in the direction of reducing emissions and I think a lot of things we could do make good sense economically as well as environmentally.

Eve Savory: Here is a question that really follows on from the last one. It's for Doug Russell: "The point is made that per capita emissions are much higher in the developed countries. Instead of arresting development in poor countries where they need more energy development for their survival, would it not be morally appropriate for the developed nations to set an example by reducing their own emissions?"

Doug Russell: Well, I think there are two aspects to this question. First of all, there is no doubt that what this hints at is the overpopulation question in developing countries, and that's a question that will have to be addressed in time. It is one that is not easy to be addressed in the types of negotiations that we've had. However there are moves afoot in the area of the UNCED talks where we are talking about the rights for women and so on, which will hopefully allow some reduction in the population growth.

Now, on the reductions in per capita emissions in the developed countries, I think that is exactly what this convention addresses. It sets out two specific classes of countries, developed and developing and the commitments to reduce emissions are only for the developed countries. The developing countries in this convention, as a first step have to produce inventories, they have to produce national strategies, they have to start thinking about how they are going to deal with this problem and money will be flowing from the developed world to the developing world to allow this to happen.

We are not asking developing countries at this point to take on specific emission reductions. However what we, the industrialized nations of the world, are doing for developed countries is setting out a plan, a process whereby our reductions or our emissions will eventually be limited.

I don't think that in this first step it's fair to say that developing countries are being asked to shoulder a large part of the burden. They are asked to prepare for how this whole thing is going to work, and we will deal with that question in later amendments to the convention.

Brian O'Brien: Could I just make a point that really illustrates a lot of the lack of logic in some of these targets? If you want to reduce global greenhouse emissions, there is, for example, a very simple step that would increase Australia's greenhouse emissions and decrease China's. China burns 1.1 billion tons of coal each year very, very inefficiently, at an average efficiency of 15 per cent or of that order.

Australia could export 200 million pot-bellied stoves to China to increase the efficiency of coal-burning in China and decrease global greenhouse emissions, even though Australia would be exporting its iron ore, and increasing its greenhouse emissions, the total world emissions would be reduced.

You really have to analyze the total problem here rather than impose artificial nation by nation targets particularly with resource rich, thinly-populated countries like Canada and Australia.

You have to analyze the total problem, not the slogans.

Bronwin Boulton: I'm Bronwin Boulton from the Thompson Watershed Coalition. First, I have a short comment and that is that in a panel this size I'm a little disappointed not to see a single representative from one of the recognized Environmental Groups present.

I have been looking at Brian O'Brien's greenhouse Holy War document here, full of references to religious wars and flatulent sheep. The only thing worse than a flatulent sheep is a bleating idiot. The references here in Dr. O'Brien's paper, of which there are five; two of them are from documents that Dr. O'Brien has chosen to attack, the other three references are all to papers by Dr. O'Brien himself.

My question is: Is there any publishing scientist in the world at all besides yourself that supports your views?

Brian O'Brien: Yes, several. For example, the Inter-Governmental Panel on Climate Change, the report by Halton et al. in June 1990, and the IPCC reports from Guangzhou in January this year. The science is straightforward. The speakers tonight agree with the science.

Bronwin Boulton: No, I am sorry, you didn't understand my question. I asked who supports your views, not supports your science. I know it's everybody's science and we all support it.

Brian O'Brien: You tell me the view that you criticize and then I'll respond.

Bronwin Boulton: Well, you say on one hand that politicians are pragmatic and on the other hand you say that politicians are supporting this greenhouse idea which is anti-development. Now to my knowledge, politicians, pragmatic politicians seem to be for development.

Brian O'Brien: The answer, although your question isn't very clear, is that the politicians are pragmatic, they want to be re-elected. There is, you've all heard of the NIMBY Syndrome, there's also the NIMTOO syndrome. Not in my term of office syndrome. I mean, we

can go on all night but it's a waste of people's time. We can talk later, but that is not a paper, it is a note. If you read the cover, you'll see it's a note.

Eve Savory: Now a question for Dr. Margolick: 'You indicated that carbon taxes are more popular than tradeable emissions permits. Are you also arguing that taxes are a more effective economic instrument or simply easier to implement?'

Michael Margolick: They are probably easier to implement. Your conventional economic theory tells you that a system of tradeable permits is economically more efficient and I won't go into the reasons for that. The only reason that I say that they are more popular is because there are some carbon taxes now in place and there are no systems of tradeable permits now in place. I mean I can imagine a time when there might be a global system of tradeable permits that would allow for "economically efficient allocation of greenhouse gas reductions" but I don't know how far off that is.

Andrew Roe: I am Andy Roe, with the Sage Foundation, a Vancouver-based non-profit recycling group. My question is to Dr. O'Brien and I trust I won't be fractious. I would like to ask you if we move in the direction of better and more responsible environmental practices, what do we lose in relation to what the cost would be if you are wrong?

Brian O'Brien: Let me point out again that all I am suggesting is a more deliberate pace towards policy formulation. The policy formulation is based upon the mindsets that were created in 1988. I am arguing not so much the end-product but the pace and the fanaticism if you like, with which the 1988 targets are being pursued. I admit that there are obvious pluses in the whole issue. The increased energy efficiency, the increased recognition of world-wide resource utilization, sustainable development; all of these sorts of pluses. But if the rises in sea level that were predicted in 1988 are now predicted a hundred years further on, then surely one has time to deliberate rationally, rather than moving precipitously in this feverish rush. That's the point.

Doug Russell: I guess, Brian, that I am one of those who you characterise as being caught up in the fever of the moment. I was at the Toronto conference in 1988. I have also followed this issue very closely. I don't think most of the people in this audience, or most of the people that are looking at problem, would agree that we have been moving at a feverish pace. I would also indicate that the world-wide representation at the convention that we held is another indication of broad support.

It is not a Draconian kind of convention. It is one that is indicative of a flexible and phased approach. It allows you to talk that first step. It brings all countries on board, it moves us all in the same direction. It may not move as far as some want, it may move farther than

others want. I certainly know that a number of major lobbying groups from some major industrialized countries who were hanging around the back of the conference halls during all these negotiations were not particularly happy with this convention. For exactly opposite reasons, some of the environmentalists were equally unhappy. They felt that we should be going directly to the 20 per cent CO₂ reduction.

I think that the fact that perhaps there is a balance of criticism toward this convention is probably a healthy situation, that you have taken a reasonable first step. We have all jumped in the pool at the same time. We may not all be up to our necks but at least we are in, and people are trying to swim in the same direction.

So I disagree that there has been a tremendous amount of over-reaction in this. I think it's been a measured reasonable response and one that as science comes on board, it allows policy development to continue and as we learn more and we sense the public mood, the feeling of how things are going to evolve, things would be changed accordingly. So I cannot accept the idea that we jumped into some Draconian type of convention at this point. Quite the opposite. I think it's a realistic first step.

Douglas Ross: Just briefly, it seems to me that if there is a danger, it's that we are going too slowly. Much too slowly. Maurice Strong's two comments last week I think are appropriate. He said, "If Rio doesn't succeed it will be the greatest breakdown of all time for the international community and perhaps the beginning of a rich-poor war. This will be the turning point that causes the key polarization, the next polarization in world politics." He went on to say, "We've all lost our innocence, I don't think we can wait another 20 years. We have been going deliberately, too damn deliberately. The Earth has cancer. In the early stages the symptoms are minimal but by the time they become acute it's too late. We are dealing with a living organism here. This is not just a physics problem."

Michael Margolick: I will make one quick comment and ask a rhetorical question here. Suppose, strictly for the sake of argument, that there is no greenhouse effect. In other words that a bunch more scientific research is done and five years from now people realize that the world isn't going to get warmer as a result of people and factories and cars and so on emitting carbon dioxide. Just hypothesize that for a minute.

Does that mean that all of the energy conservation measures and lifestyle changes and so on that are being proposed to counter this, does that mean that they shouldn't take place? No, not to my way of thinking, and I've been an advocate of energy conservation for a long time, to my way of thinking it doesn't matter whether or not the greenhouse effect is a real thing or not. Most of the measures that would be taken to offset greenhouse

gas emissions should be done anyway in order to fulfil other objectives.

Eve Savory: I have a question here which was addressed to Gordon McBean or Doug Ross and I think I'll direct it to you, Gordon, because in a sense Doug has already given his answer. It also quotes Maurice Strong, who has said that the worst thing that could happen at Rio de Janeiro would be a quiet failure. If it's going to be a failure it has to be spectacular failure. Now the question is: "How would you rate the recently concluded climate convention, success or failure?"

Gordon McBean: Well, I think the convention, as Doug has indicated, is a success in the sense that all of the countries have agreed to it and when you get an agreement among 150-odd countries, that, in itself, is a major achievement. I guess some people had expected more of it in terms of actually setting emission targets although I personally think that it might have been more difficult if we had set targets where we weren't quite sure what they meant. So I would argue that it is a success. But it is only a first step, and we clearly have to follow with many more steps. I think that the process has been started and that is the important aspect of it, not so much the detailed words of the first step of the agreement.

Jeff Blight: My name is Jeff Blight. I was a commercial fisherman for ten years. My question is addressed to Dr. Hobson but first I'd like to give just a brief preamble. What I am going to ask him about is fish, a pelagic species of fish, or pelagic species in general. Pelagic meaning that those fish out in the ocean, around the middle of the water column or perhaps up towards the top of the water column. When those fish spawn and reproduce, they lay their eggs at the top of the column and they float there.

My two questions for you are: "First, how many species of fish lay their eggs at the top of the surface of the water, on the top reaches of the water column? and secondly, what are the possible effects of UV radiation on sterilizing those eggs?"

Louis Hobson: Many fish.

Jeff Blight: That's what I thought.

Louis Hobson: Also, you've left out a whole group of shellfish-type organisms, the zooplankton that lay eggs up in the surface waters as well. We don't know very much about the impact of ultraviolet on those eggs at this point in time. We do know that many of the crustaceans, at least, have a lot of pigment in the eggs called carotenoid pigment, an orange pigment that's very effective at absorbing ultraviolet A. Not ultraviolet B, but ultraviolet A; and many of those eggs are only in the surface water for a short period. As they start to develop they start to sink away from the surface layer and develop in deeper water.

During this near-surface period, they could be damaged, but no one at this point knows how severe that kind of damage is. Ultraviolet irradiation studies in laboratories certainly kill the eggs, but we again have difficulty extrapolating from what's done in a laboratory scenario to what's going on in the ocean.

Jeff Blight: Right, and the conclusion to my question, I would think that it would be very important for people to think about what the ramifications of that are when you are told that we don't know. This is the basis of the food web for the oceans. Pelagic fish, such as Pacific Hake which has the largest biomass of all fish on the west coast of North America, lay their eggs on the surface. For some reason, in the 1950s, their spawning shifted from off the coast of Baha California and moved northward, off the coast of central California. Now Baha, in Mexico, no longer has that fishery resource. But more importantly, it is believed that they shifted because of a sea-temperature change. So our oceans are very dependent or can be affected very easily by things like possible sterilization of eggs and climate changes shifting the spawn location.

I am not done. And I would want you to know about this because this is the basis for our ocean's life. Fish and Zooplankton and phytoplankton are on the business end of the food chain for our planet's oceans....

(At this point, the Chairman ordered the mike cut off.)

Eve Savory: I do apologize. Your point was a very interesting one and important. It's hard to cut any of you off because all of your questions are informative and I thank you for that. But there are so many people who want to ask questions in the time remaining, that's all.

I have three questions for Doug Russell, two which are just points of fact and one which requires a considered answer. First, "With regard to the commitment to action, is China considered a developed country, yes or no?"

Doug Russell: Well, the last time I looked, China was classed as a developing country.

Eve Savory: Right. And the second is: "How many newly developing countries are not participating in the climate change convention?"

Doug Russell: Well, I think that you'll find that there's about 162 countries in the world, give or take a few of the new Baltic States that are coming on stream and we had 147 at the last round who all said 'yes' in a consensus.

As to how many will sign, I suspect it will be less than that, but at least among the negotiators there was consensus among 147. A few will not participate.

Eve Savory: The key will be in the signing and the ratifying. I can tell you that I was speaking to an Indian delegate right after the agreement was reached - Doug doesn't like this story - who said it was clear to him that it was really an OECD convention. And India was not happy with what was being agreed to at all.

Now the final question here is: "If the agreement is not a treaty, how can there be any significant compliance? It appears that compliance is not important because there is no mechanism for penalties."

Doug Russell: Well, it's not the sort of treaty that would allow you to take a country to court, to The Hague, for example, and say, "Well, I'm afraid you fell 3 per cent short of your goal, we are going to sue you." That isn't the nature of the treaty. Rather, it relies to a large extent on moral persuasion and the reporting and review mechanisms, those mechanisms that are in place to ensure that whatever people submit will be the actual compliance aspects of it.

I think what it really points to is that it is a transparent process, it's an open process, it's one where everybody will have an opportunity to see how well all nations are stacking up, and there will be a tremendous amount of political pressure brought to bear, and it will be a politically accountable type of regime as opposed to one of a strict international treaty whereby you bring people to court. Having said that, though, there are provisions for compliance. The commitments that are there in the convention do mean that you do have to report on the actions you are talking. If you do not report on those actions there are provisions for compliance, although at this point I don't think anybody is going to be hauled into an international court as a result of missing this first step. At the same time, I think that the real key is the political pressure that will be brought to bear in the longer term.

Sidney Haskell: I'm Sidney Haskell, of the Carmanah Forestry Society. I want to address what I see as a sacred cow that hasn't been brought up by the panel so far, and it's very appropriate in British Columbia because our forests seem to be an international scandal. From my understanding, our forests would be incredibly impacted by global warming, by ozone depletion and so forth, and I believe this has been covered in various federal climate change reports. I'm very surprised not to hear this mentioned. As I say, this may be a sacred cow that we are not supposed to talk about today.

I would like to get some clarification from any of the speakers. One thing I noticed that Michael Margolick happened to mention, he happened to mention that burning black liquor is not so bad because maybe the wood would rot on the ground anyway. I think we have to look at the rate at which things are happening. Because we know wood rots over 300 years but smoke

stacks put it up really fast. So I would like to get a little bit of clarification on what this means to our forests and also maybe Michael could clarify that for me.

Michael Margolick: I didn't really have a chance to go into it in detail. But since you asked, let me put it this way: although I don't believe for one moment that forestry is actually practised this way, but if you could imagine a totally renewable forest system in which the rate of biomass replacement was equal to the rate of biomass removal and you had a 100 per cent sustainable forestry sector, then the net rate of carbon emissions to the atmosphere within that entire sector would be zero.

Let me put it another way, if you were taxing the emissions at the smoke stack, you should also be crediting the reforestation efforts to an equal degree. I don't believe B.C. or Canadian forestry works that way. I don't know of any forestry sector in the world that works that way but I am just saying that it is an open question and I'm sure it will be debated at great length among all the technical experts as to whether the emissions at the stack from biomass fuels should be taxed at the same rate as fossil fuels which go up the smoke stack.

Should it be 100 per cent, should there be no credit allowed for some aspect of sustainability of the forest or should it be anywhere down to zero? Our research shows actually if we credited it at a rate of 50 per cent, just for the sake of seeing what it would do to the industry; and at that point, quite coincidentally, it turned out that the rate of emissions of the carbon per pound of steam produced are about the same as for natural gas and wood waste. So there's the balancing point between those two fuels. If the forest company were to have a carbon tax imposed, then our research suggests that if the tax at the smoke stack on wood waste were less than half that of natural gas, then the industry would prefer to burn wood waste and if it were more than half, it would prefer to burn gas.

John Reynolds: Madame Chairman, I'm John Reynolds, from the Prince Edward Island Maritime Electric. Now, we've heard about reducing carbon-dioxide emissions and carbon taxes and all the good reasons we should be doing this, but we haven't heard one word about what it's all going to cost. If we don't know what it's going to do to our electricity rates, don't know what it's going to do to pulp and paper prices, don't know what it will do to the cost of steel and a thousand other things we use everyday; how can we make any sort of judgement as to whether we can afford all this altruism? Particularly if China's coalplant emissions will swamp any improvements we achieve?

Eve Savory: Mr. Reynolds, I'm sorry. I'm afraid that we have finally run out of time. It's now past 10:00 o'clock, so I am going to close these proceedings. I would like to thank our panellists, Dr. Gordon McBean, Mr. Doug Russell, Dr. Brian O'Brien, Dr. Louis Hobson, Dr.

Mike Margolick and Dr. Douglas Ross for their very interesting reviews of the global warming situation, and what we should be doing about it. I'd also like to thank B.C. Hydro, the B.C. Environmental Network and Torrie and Associates, the sponsors of this evening's presentation, and finally, I would like to thank all of you for attending, for your attention and for posing some really challenging questions to our panellists.

This session is now adjourned. Good evening.